September 1959

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57 Reactors In The Sea

BUILDING THE NUCLEAR NAVY... p. 73

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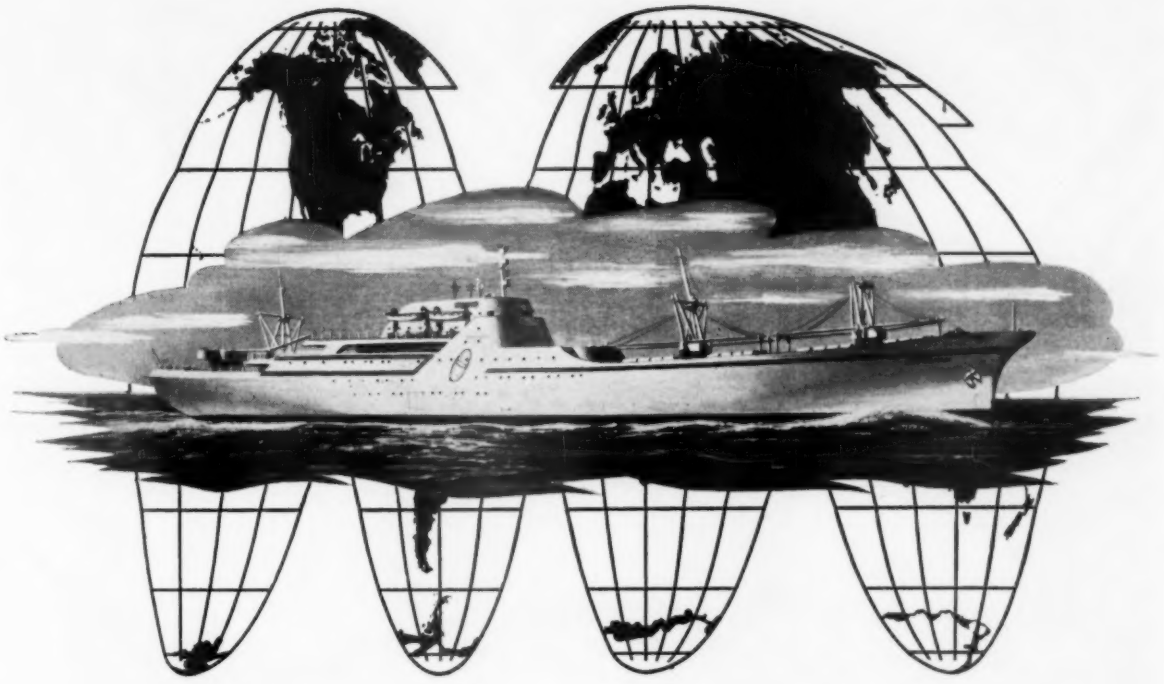

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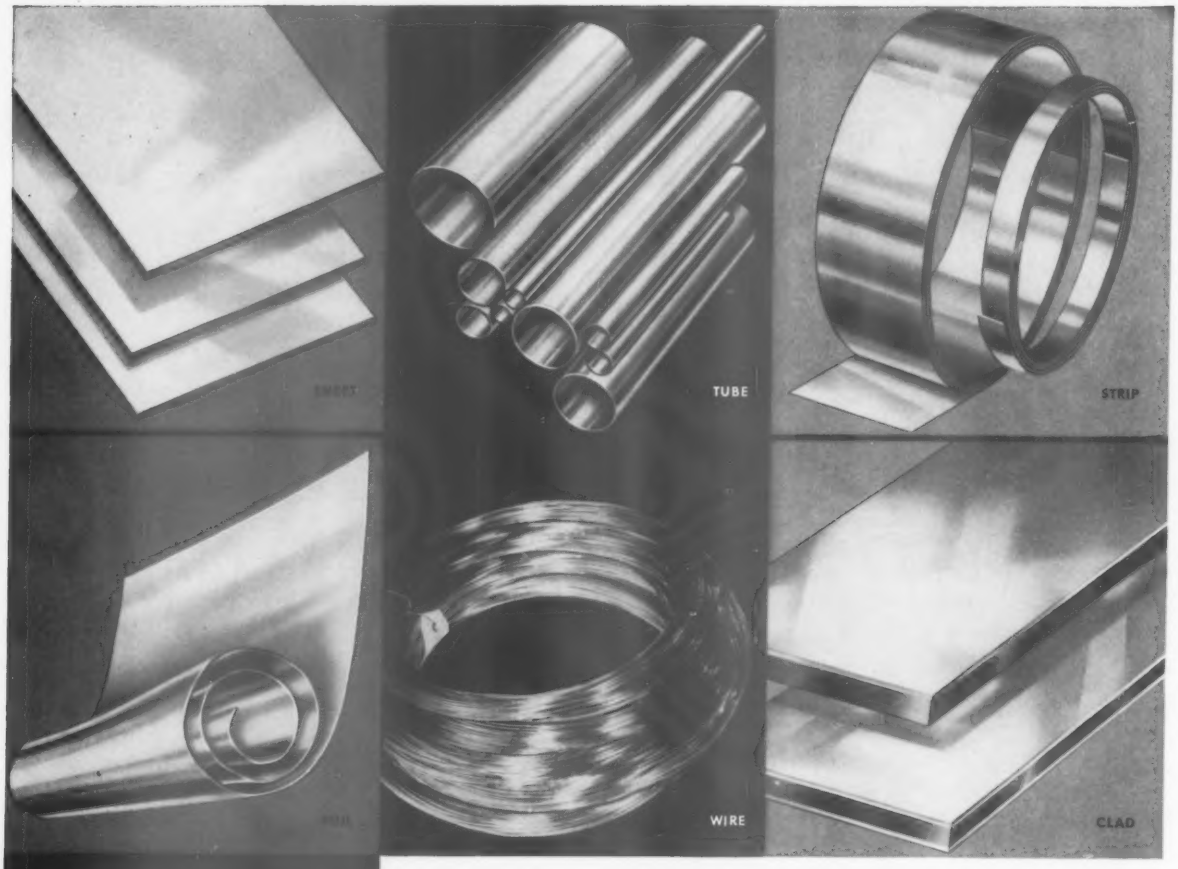

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More about NUCLEONICS on next page ▶

About NUCLEONICS

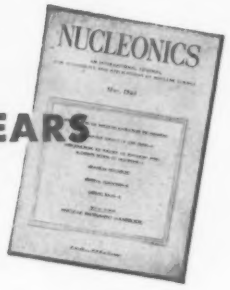
Nuclear Navy Revisited

In our lead story this month News Editor John Kenton reports on two loves, the atom and the sea, as embodied in the ever-more-nuclear U. S. Navy. Even as the nuclear Navy has grown since John covered it in the July 1957 NUCLEONICS, so has the magnitude of the reporting job required. This report fills more than twice as many pages as its predecessor, and legman Kenton covered more than four times as much territory in digging up material for it. He visited 5 of the 7 shipyards engaged in the nuclear program (all those on the Atlantic coast), toured the plants of nearly a dozen suppliers, attended the launchings of half a dozen nuclear vessels, and talked with more than 50 industry figures and naval officers from Secretary Franke and Admiral Burke down (but not Rickover, once again incommunicado). The distilled essence of John's findings (his original notes could fill a book) are there for you to read on p 73.

—*The Editors*

MIR I DRUZHBA. Editors of NUCLEONICS extend a private welcome to some of the Russians staffing the atomic energy sector of the Soviet exhibit at New York's Coliseum. From left to right, seated: Managing Editor Dan Cooper, fusion researcher Igor Podgorny, Editor and Associate Publisher Jerome D. Luntz, atomic exhibit chairman and member of editorial board of *Atomnaya Energiya* Valery Kalinin; standing: Associate Editors Tom Cramer and Hobie Ellis, physicist Anatoli Filippov, Marketing Editor Jim Thomas, reactor theorist Vadim Artamkin, NUCLEONICS editors Hal Davis, John Kenton, Bob Adamson. For an impression of Soviet exhibition see p. 90.

10 YEARS AGO



First pile-produced C^{14}. Although carbon-14 was first discovered in the 1930's, only with the advent of the nuclear reactor did it become possible to produce multi-millicurie amounts of isotopically pure material using the $N^{14}(n,p)C^{14}$ reaction. Early in 1945, with the war still going on, space was provided in the Oak Ridge X-10 reactor for the first C^{14} "factory." Ammonium nitrate solution was circulated through an in-pile tube and the C^{14} produced extracted in an external apparatus. A total of 440 mc of C^{14} were produced before the apparatus was removed to save on pile reactivity. Out of this precious supply came the first mass-spectroscopic observations, reasonably accurate half-life determinations, many physics experiments and "tracer experiments . . . too numerous to mention."—L. D. Norris, A. H. Snell, NUCLEONICS **5**, No. 3, Sept. '49, p. 18.

Gesund Physik. The small-format NUCLEONICS had a sense of humor. How else do you account for Evan C. Evans' "Lebsensform fur das Monitor"? On the theory that not all old jokes are bad jokes, you might want to dip into the files and reread this.—NUCLEONICS Sept., 1949, p. 74.

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NUCLEAR REACTIONS

A Partisan for Particles

DEAR SIR:

The recent letters of Drs. K. H. Morganstern and P. C. Aebersold (NU, June '59, p. 6) have introduced a timely discussion regarding the relative usefulness of radioisotopes and particle accelerators for industrial processing. . . .

In the interest of clarity, I should like to comment on Dr. Aebersold's letter, in which he discussed three major contributions made by AEC to the broad field of radiation utilization.

1. It is true that AEC has sponsored research in physics, chemistry, biology and medicine, using high-energy particle accelerators. With very few exceptions, however (in fact, High Voltage sales reflect no exceptions), these particle accelerators have been of the positive-ion variety or have been low-intensity electron machines for basic research. High-intensity Van de Graaff development has been sponsored almost exclusively by industry or through High Voltage's own research program.

To the best of our knowledge, the resonant transformer and the Dynamitron developments have been similarly sponsored. Our knowledge of the linear electron accelerator comes from extensive developments supported by Office of Naval Research. The programs currently being undertaken by the Army Quartermaster Corps and the National Institutes of Health represent two other government activities not sponsored by AEC.

We can only conclude that, whereas AEC has indeed promoted the general field of particle acceleration, its contribution to low-cost, high-powered electron machines has not been significant.

2. We would like to take issue with Dr. Aebersold's comment that "high intensity radioisotope sources are not competitors of machines per se." In the fields of industrial radiography and cancer therapy, isotope sources are directly competitive with supervoltage machines in a most aggressive sense. Only the established low cost of cobalt-60 makes this competition possible. How realistic this cost is, as measured in terms of normal commercial practice, is conjectural.

In a powerful, indirect sense, the technical information released by AEC has tended to confuse the market and hence has caused deferment of many important projects. The exploitation of small cobalt sources for research has given a false sense of participation to a number of companies, despite the fact that these small sources offer neither the dose rate nor an approximation to industrial processing conditions that would make an extrapolation realistic.

3. We agree wholeheartedly with Dr. Aebersold that the economic situation is not clear-cut, but we take issue with the reasons he gives. The economics of particle accelerators are well known today. These machines are sold on a fixed-price basis with firm costs of construction for industrial processes. The results are being proved in the field on a rather large-scale basis. Based on our present knowledge and our demonstrated ability in the past to predict, new developments in particle accelerator techniques can be promised on a guaranteed basis. What clouds the situation is that the projected costs of radioisotope installations are hypothetical and incomplete, as seen by experienced designers of accelerator installations.

Equipment providing penetrating radiations at capital costs well below $10,000 per kilowatt are being quoted by us today for installation within the next few months.

Based on the equivalence of 70,000 curies of cobalt per kilowatt of ionizing radiation (this assumes an efficiency of isotope utilization much greater than can actually be realized today), the cost of cobalt would have to drop to 14 cents per curie to become competitive. It is doubtful whether this isotope could even be shipped from the nuclear reactor to the industrial installation for this amount. Furthermore, accelerator developments now under way in our plant can substantially lower current capital costs per kilowatt of radiation.

Our attitude with respect to the AEC Office of Isotopes Development should not connote our disagreement with their basic goal, that of developing widespread application of radioisotopes in science and industry. We believe that AEC is conducting an extremely important program in that direction. Our objection is that AEC is concentrating too much effort in an area already being served by a growing accelerator industry.

—E. ALFRED BURRILL
Vice President and Sales Manager
High Voltage Engineering Corporation
Burlington, Massachusetts

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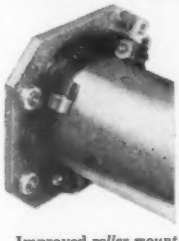

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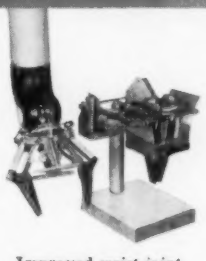

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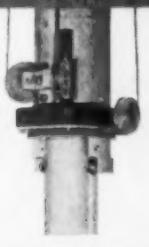

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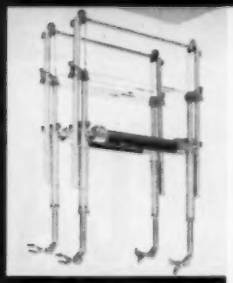

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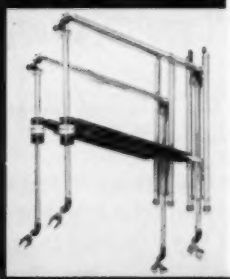

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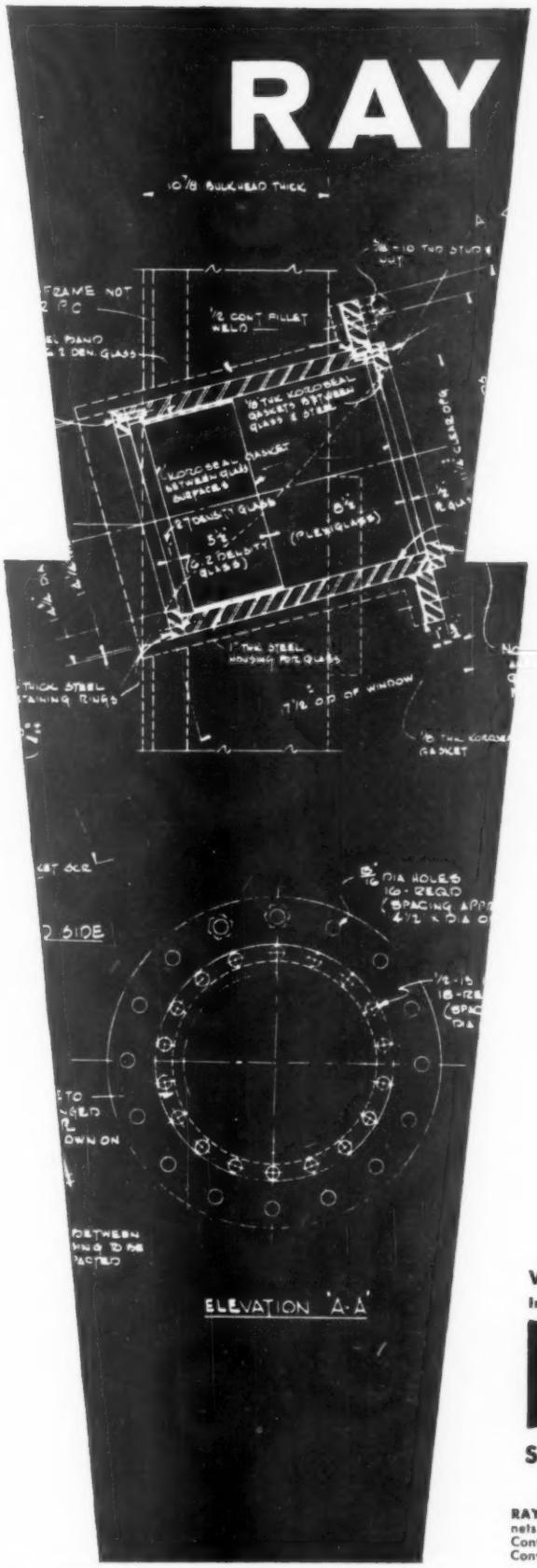

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Proved, too, is the carefully controlled quality of Mallory-Sharon zirconium mill shapes. As America's largest integrated producer of special metals, Mallory-Sharon is in a position to exercise strict quality control at *every* stage of production—from raw materials to finished mill products.

For proved reliability of product and unmatched technical know-how in applying zirconium and other special metals, contact Mallory-Sharon. Our strong Service Engineering group is ready to assist you. Or write for—"Technical and Application Data on Zirconium and Hafnium".

What this means to commercial users

Mallory-Sharon's large-scale chunklet production facilities are now in full operation at Ashtabula, Ohio. Chunklet prices are steadily being reduced . . . reductions which are immediately reflected in lower prices of zirconium mill products. With 1,000,000 lbs. of zirconium to be available for commercial use this year, *now* is the time to investigate the economic advantages of zirconium in commercial atomic power applications.

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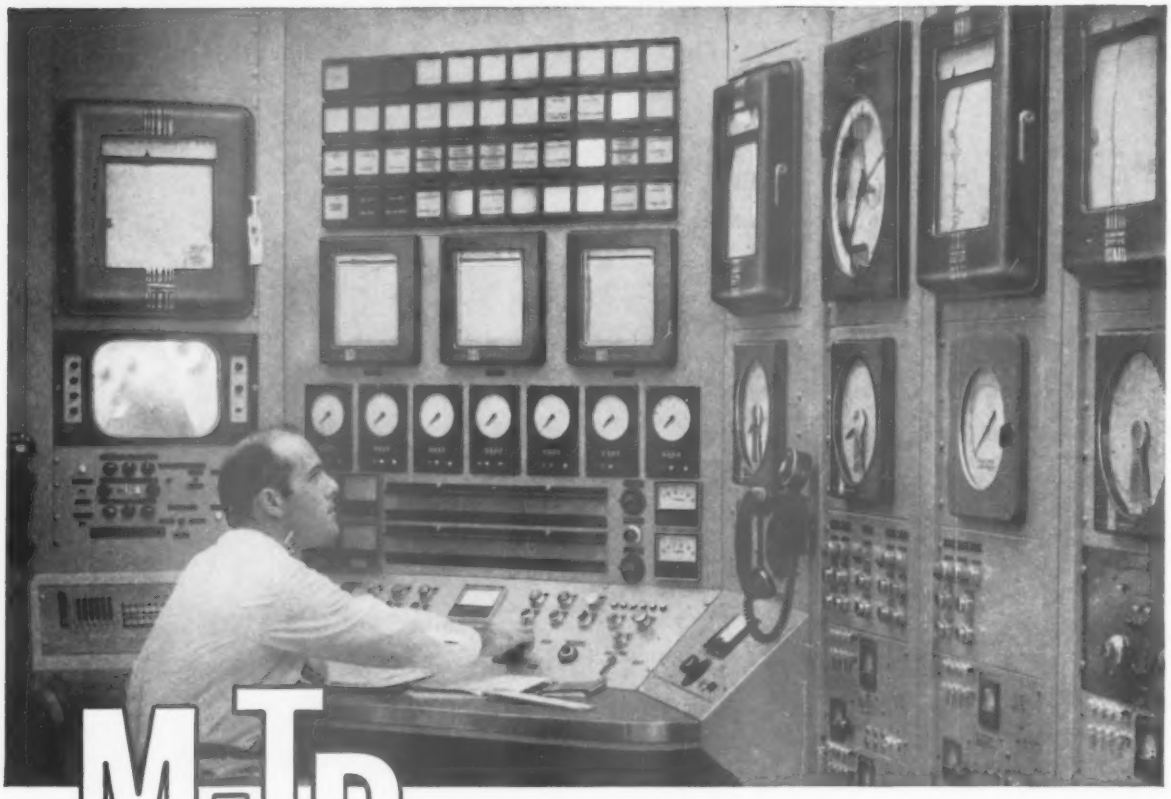
Integrated producer of Titanium · Zirconium · Special Metals



MITR

Another L&N control system guides operation of research reactor

At Massachusetts Institute of Technology, scientists depend on L&N instrumentation for control of their new research reactor. Designed by Dr. Theos J. Thompson of MIT and constructed by ACF Industries, this heavy water reactor facility is located in the heart of Cambridge. Specifications demanded not only accurate and dependable controls, but also, the necessary engineering experience so important to the safe and successful instrumentation of a reactor. Both were supplied by Leeds and Northrup.

For the MITR system, standard Speedomax® G Recorders monitor radiation, temperature, heavy water flow and temperature difference. A Speedomax G X-X Line Recorder computes the thermal power from D_2O flow and temperature difference. Speedomax H Recorders chart log count rate, log N, temperatures, and reactor power. A discontinuous P.A.T. servo amplifier positions the control rod automatically to regulate reactor power level, with an 18-range micro-microammeter following flux from start-up to operating level.

For our new booklet "Nuclear Power Reactor Control Systems," write Leeds and Northrup Co., 4936 Stenton Ave., Philadelphia 44, Pa.

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KOLLMORGEN Remote Viewing Systems...
used in most atomic installations

Photo courtesy Phillips Petroleum Company

A Phillips Petroleum Company technician observes radioactive metallurgical specimens through a Kollmorgen Hot Cell Periscope installed at the Materials Testing Reactor Hot Cell, National Reactor Testing Station. The periscope helps determine characteristics such as tensile and impact strength, hardness, weight and density changes. Macrophotography of specimens is also performed through the periscope.

Radioactivity, caustic fumes, blast forces, inaccessibility and other adverse conditions hamper observation and inspection. To overcome these conditions, more and more installations in a widening range of industries are using Kollmorgen remote viewing instruments. Kollmorgen specializes in the design and manufacture of instruments and systems for detailed observation under difficult or apparently impossible circumstances. Most of these devices can be readily adapted to photography or television.

We have recently prepared a twenty-four page illustrated brochure which describes our facilities and primary fields of interest. For a copy, please write to Department 119.

and from Cape Canaveral to the North Pole

The Nautilus and her sister ships of the Atomic Fleet, like most other U.S. submarines, are equipped with Kollmorgen periscopes. These instruments require highly precise optical, mechanical and electronic components.

Kollmorgen Bunkerscopes are used at Cape Canaveral for observation of missile launching operations and static tests. Bunkerscopes allow detailed observation from a considerable distance with no danger to the operator. Images appear in bright, clear, natural color. There are no maintenance costs with these Bunkerscope operations.

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WCC METALS GUARD THE NUCLEAR

NAVY'S SPARK OF LIFE!

Advanced power plants have made our nuclear navy the most powerful sea force ever launched. Deep in the innards of these reactors, fulfilling vital functions, are the metals *produced and fabricated* by the Wah Chang Corporation . . . who for more than 41 years has aided in the expansion of our nation's technology.

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233 Broadway
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BRINGING TOMORROW CLOSER WITH NEW METALS

The C-E Nuclear Division at Windsor, Conn., is staffed and equipped for all phases of nuclear reactor work except the fabrication of heavy components (see below). Its facilities range from those required for reactor development and design to those used for assembly and test of reactor systems. They include two Critical Experiment Facilities; Metallurgical, Mechanical, Electronic, Chemical, Health Physics, Research and Development Laboratories; computer systems; and the Core Manufacturing Plant, part of which is shown at right.

COMBUSTION'S ROLE IN THESE facilities have produced —or are producing

More than 1,600,000 sq. ft. of manufacturing floor area comprise the Chattanooga Division of C-E. Here, all heavy nuclear components (reactor vessels, steam generators and pressurizers) are made. The 520-ft.-long Nuclear Building, part of which is shown at right, was created especially for the manufacture of these components and contains many large machine tools designed to meet the exacting needs of the nuclear industry. Manufacturing facilities are backed by metallurgical, mechanical, photoelastic, development, fuels and chemistry laboratories; and by digital and analog computer systems.

Installation	Cores	Reactor Vessels	Steam Generators	Pressurizers
Land based prototype of the submarine Seawolf		1		
SSN 575—U.S.S. Seawolf		1		
Land based prototype of Hunter-Killer Submarine	1	1	2	
SSN 597—U.S.S. Tullibee Hunter-Killer Submarine	1	1	2	
Land based prototype of Guided Missile Destroyer Leader		1		
DLGN-25—Guided Missile Destroyer Leader U.S.S. Bainbridge		2		
Land based prototype of Aircraft Carrier		1		
Aircraft Carrier CVAN-65—U.S.S. Enterprise		6		
Guided Missile Cruiser CGN9—U.S.S. Long Beach		2		
Land based prototype of Radar-Picket Submarine		1	2	
SSRN 586—U.S.S. Triton Radar Picket Submarine		2	4	
Various Attack and Guided Missile Submarines	6	7	8	9
TOTAL	8	26	18	9

OUR NUCLEAR NAVY

THIS work for the Naval Reactors Branch of the AEC

COMBUSTION ENGINEERING

C-234

Combustion Engineering Building, 200 Madison Avenue, New York 16, N.Y.

Turn page for other C-E Nuclear Projects

OTHER C-E NUCLEAR PROJECTS

Apart from its work for our Nuclear Navy—about which see the previous two pages—C-E and its affiliated companies are engaged in a wide range of activities in the nuclear field. Some of the more notable work in this area is outlined below.

REACTOR SYSTEM DESIGN AND DEVELOPMENT

For the Puerto Rico Water Resources Authority, a comprehensive design study, under AEC contract, is being made to determine the best means of adding nuclear superheat to a boiling water reactor. Under the terms of a more recent AEC contract, further work relating to the nuclear superheat concept will be performed to permit determination of its feasability and to permit the Commission to proceed with final design and construction of a prototype plant if such construction is indicated.

For the East Central Nuclear Group, Inc., and the Florida West Coast Nuclear Group, design, research and development work covering a gas-cooled, heavy-water-moderated prototype reactor has been in progress for some time.

In association with Stone and Webster Engineering Corporation, a design study of an advanced type of large, pressurized-water reactor power plant has recently been completed for the AEC.

For the Atomic Energy Commission, a study has been undertaken to determine the best and cheapest way of producing large quantities of radioisotopes in a reactor.

FUEL CYCLE DEVELOPMENT

Under contract with the AEC, and as part of its fuel cycle development program, the Company is currently engaged in the:—

Development and testing of uranium oxide fuel elements.
Development and testing of homogeneous ceramic fuels.
Development of an apparatus for ultrasonic roll bonding of fuel elements.
Study of slightly enriched water reactor system with a high conversion ratio (physics).

REACTOR OPERATION

Under contract to the U. S. Army, the Company is operating the prototype boiling water reactor power plant known as SL-1 [Stationary Low (power) Number 1] located at the National Reactor Testing Station. In addition to assisting in the training of military personnel in its use, the Company is performing further research and development work aimed at evaluating plant performance and in preparation of a referenced preliminary design for a modular, air-transportable, 800 eMW, Boiling Water Reactor power plant.

REACTOR COMPONENT DESIGN AND MANUFACTURE

C-E has designed and manufactured reactor vessels of many different kinds and sizes. Completed work and work in progress include:—

The 235 ton, stainless-steel-clad reactor vessel for the pressurized water plant at Shippingport, operated by The Duquesne Light Co.

The complex stainless steel reactor vessel for the sodium cooled, fast breeder reactor of the Enrico Fermi Atomic Power Plant, designed by the Atomic Power Development Associates. The reactor plant will be operated by the Power Reactor Development Co. and will deliver electricity to The Detroit Edison Co. system.

The reactor vessel for the boiling water reactor to be installed at the Humboldt Bay Nuclear Power Station of the Pacific Gas and Electric Co.

SPECIAL SERVICES

Design, engineering, procurement and construction liaison (by the Lummus Co.) of the Heavy Water Area, the Nitric Acid Recovery Unit and the Uranium Oxide Recovery Unit of the Savannah River Plant of the A.E.C.

The planning and control of a series of irradiation tests on fuel alloys to high burnups under anticipated environmental conditions in the Materials Testing Reactor in Arco, Idaho.

Irradiation studies, fabrication studies, evaluaton studies of the general properties of materials, quality control, isotopic analyses, strain gauge and photoelastic testing, basic and applied research in ferrous metallurgy.

HEALTH PHYSICS

Numerous projects involving bio-assays, decontamination, environmental monitoring, radiochemical analyses and radiological safety programs.

C-E'S ROLE IN THE NUCLEAR NAVY
(preceding two pages)

COMBUSTION ENGINEERING
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C-234

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

MgO spells opportunity

IMC reports on another outstanding property of its new High Purity MgO — remarkable heat resistance.

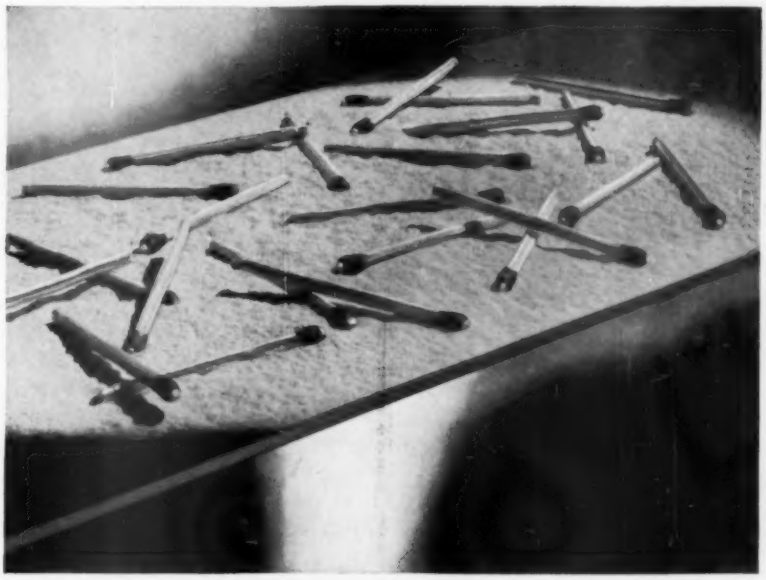
For many years, International's potash mining and refining operation at Carlsbad, New Mexico, has been producing large amounts of by-product magnesium chloride brine in conjunction with potassium sulfate. We are recovering values from this magnesium chloride by thermal decomposition to produce magnesium oxide. The product is better than 99% pure — highest purity ever achieved in carload lots.

Unbounded application

Heat resistance is one standout property. As a result, a firm is presently experimenting with it to develop a rocket nose cone capable of re-entering the earth's atmosphere. Another of its chief virtues is ease of handling, due to its low hydration rate.

Using MgO as an addition or substitution, many chemical process industries have been able to impart desirable — and hitherto unattainable — properties to their products. To elaborate:

- Improving the physical and chemical characteristics of magnesia has resulted in substantial savings. Using MgO as an extender, it's possible to obtain a high purity blend at low cost.
- Chemical manufacturers are making high-purity magnesium salts and chemicals from International magnesium oxide because of its relatively low cost and easily controlled reaction rates.
- By replacing ordinary alkali precipitants with MgO, several plants have been able to increase their process efficiency and reduce production costs.



Among its other applications: Electric furnace fusion for high temperature applications . . . in high-grade ceramic and glass formulations . . . for acid neutralization and uranium ore treatment . . . in thermocouples . . . as a substitute for alumina. Due to its low boron content, this International product has been the main source of MgO for U.S. Atomic Energy Commission applications. And the limits of its potential are nowhere in sight.

Send for a sample

If you're interested in the possibilities of high-purity MgO in your operations . . . if you detect promise for its use as a replacement material or in an entirely new application — use the coupon below. Our research staff is prepared to explore end-use problems with you. We will be happy to furnish adequate samples for experiment, and to supply technical assistance where required.

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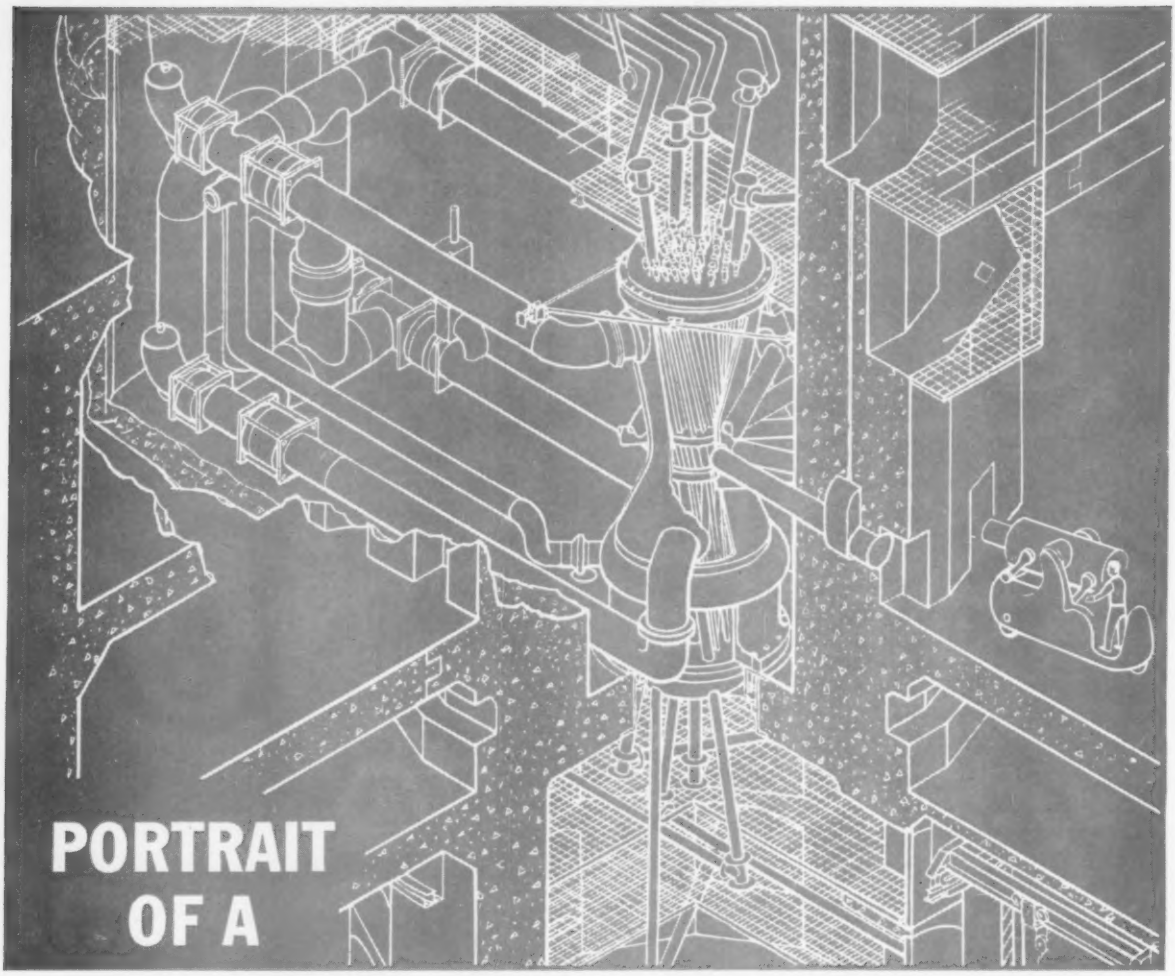

TEST REACTOR

Five nuclear reactors are in various stages of development at NDA. Each differs from the others, but all bear the stamp of true progress.

Progress in design is an NDA hallmark and accounts in part for its success in a demanding field. Equally important, however, is the ability of an organization to move from concept through engineering design, materials development, laboratory experimentation and critical testing. In these, too, NDA's reactors show invention and originality.

NDA's complete reactor capabilities are exemplified in METR (above), a 50-megawatt Materials and Engineering Test Reactor, the first of which is now under construction at Mol, Belgium. Beginning with the core itself, a unique design which combines extremely high neutron flux with simple, independent access to each fuel and experiment tube, METR I will be a vital part of one of the world's great nuclear centers. METR is typical of the family of reactors now under design or development at NDA for power, propulsion and research.

OPPORTUNITIES EXIST AT NDA FOR QUALIFIED SCIENTISTS AND ENGINEERS

a complete reactor company

NDA — NUCLEAR DEVELOPMENT CORPORATION OF AMERICA

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NDA EUROPE 31, Rue du Marais, Brussels, Belgium

ROUNDUP of Key Developments in Nucleonics

Expect New Radiation Council to Set Exposure Policy

The Bureau of the Budget has recommended to President Eisenhower that he give more responsibility on radiation safety to the Dept. of Health, Education and Welfare (HEW) and that he establish a Federal Radiation Council from among four members of his cabinet. The President adopted the recommendations as proposed.

They were submitted to him early in August after a four-months' review of federal radiation-safety activities by the Bureau, AEC and HEW. President Eisenhower ordered the study last March (NU, May '59, 27) after a congressional outcry over weapons fall-out and completion of a radiation study by an advisory committee to HEW which called attention to the conflicting promotional and regulatory responsibilities of AEC.

The White House action was expected to have these effects:

1. The four-man Federal Radiation Council—AEC Chairman John McCone, HEW Secretary Arthur L. Flemming, Defense Secretary Neil McElroy and Commerce Secretary Frederick Mueller—will begin a comprehensive appraisal of current federal programs on radiation safety and, eventually, recommend specific action to the President. As an AEC official stated it: "The Council will try to decide what the real problems are [in arriving at exposure limits, etc.] and how best to handle them." The Budget Bureau left it up to the President to name a Council Chairman but suggested that the President's advisor on science, George Kistiakowsky, be given consultant status with the Council.

2. HEW's two major health divisions—the U. S. Public Health Service and the Food and Drug Administration—will be given more responsibility on radiation. USPHS will establish itself as a collator of exposure and other data, and both USPHS and FDA will step up significantly their spending on radiation-safety research. USPHS has a fiscal-1960 budget of $2.5-million for radiation activities, FDA about $300,000; however, Flemming said additional funds would be sought from Congress this year for both agencies, in view of their enlarged roles in developing radiation data.

3. There was expected to be no significant change in AEC's functions. Pending some ultimate changes at the behest of the Federal Radiation Council, AEC will continue both its licensing and research functions. However, creation of the Council takes away from AEC any policy-making power it had and gives it to the interdepartmental body. Ultimately, the President has the final say on administration programs but the new council will have a powerful influence on the federal attitude toward our radiation activities in industry and elsewhere. Similarly, USPHS is expected to build up its authority in the radiation field and to take on an ever expanding role in setting radiation standards.

Industry Flays AEC's Proposed Rule Cutting Dose Limits

Even more vigorously than it had protested AEC's proposed reactor-site criteria (NU, Aug. '59, 21), the nucleonics industry has attacked a proposed rule decreasing radiation-exposure limits and requiring new reports to employees (NU, '59, 31).

Impressed by complaints that the rule would complicate relations with employees and the public, impose unnecessary economic burdens and seriously discourage the industrial use of atomic energy, AEC's Division of Licensing and Regulation appears likely to make extensive changes—possibly preceded by public hearings—before the rule is issued in final form.

Division Director Harold Price would not comment last month on the full extent of possible changes but he conceded that "it looks like we may have to rewrite the reporting requirement."

AEC first issued its regulations for the protection of workers and the general public against radiation hazards of AEC licensees in 1957 (Part 20 of the licensing code). Then, last April, AEC proposed a lowering of exposure limits and adoption of procedures for written reports to employees, based on 1958 recommendations of the National Committee on Radiation Protection.

Under the proposed changes, total external radiation exposure any worker could accumulate beyond age 18 would be limited to an average 5 rems/yr (down from 15 r), with exposure in any one year limited to 12 r. In addition, maximum permissible concentrations of radioactive substances in air and water would be revised—cut to one-third of present values in the case of biologically important radioactive materials. Finally, licensees would be required to furnish reports to employees showing accumulated exposure—annually or within 90 days of termination of employment. Workers would also get immediate reports on overexposures.

The industry response was so heavy and the proposal so far-reaching that AEC twice extended the period for filing comments—most recently to Aug. 31. Following this rare second extension of time, an AEC official commented:

AI winning in Spain

Atomics International and the OMR have beaten out Westinghouse in the Spanish competition of design studies for the first Iberian power reactor (NU, May '59, 34). NUCLEONICS learned in Madrid that the Junta de Energia Nuclear had wired AI announcing its decision and calling for submission of a preliminary design for the proposed plant, a 20–30 Mw(e) unit.

EBWR shut down for modification

On July 3 EBWR was shut down until May for conversion to 100-Mw(th) operation. The forced circulation and D_2O experiments (NU, March '57, R8) are postponed. Argonne will soon ask industry bids to build the new core. The old turbine will be kept, and excess steam dumped or used to heat the labs.

Now perforated for your convenience

"It looks like a lot of people think the rules are strict enough already." A cross section of these industry comments:

Exposure, Concentration Limits

Babcock & Wilcox: The proposed revisions were so detailed and restrictive that "the use of radioactive materials in industry, and the technological advances which would have been possible by their use, will not be realized."

Michigan Dept. of Health: The proposed exposure limit of 2 millirems in any one hour would cause "many of the hospitals to be in violation of the regulations." The new standards should be issued as recommendations rather than regulations.

Allied Chemical Corp. (General Chemical div.): In designing the waste-disposal system for its uranium hexafluoride production facility at Metropolis, Ill., it had relied upon the regulations issued in 1957. At present, thorium-234 and other wastes are discharged in an effluent stream of 60 gal/min. Under the lower permissible concentrations, Allied said, it would have to store the wastes in 3,000 drums—involving extra expense and additional hazard to personnel who handle the drums.

Westinghouse: The lower permissible concentrations cited in the proposed new regulations on environmental limits may impose some "design and operating hardships" for homogeneous fuel, organic moderated and possibly gas-cooled reactors.

State of New York: Cited a letter from New York City officials noting that their principal objection was "related to our attempts to counteract much of the current unfounded fear of radiation which in many cases has actually resulted in psychosomatic symptoms."

Reporting Requirement

Convair: It would have to "educate" its employees as to why the reports were being made—at a cost of $120,000. All told, the requirement "would almost double the cost of our whole health physics program. For years we have proceeded on the premise with our employees that it is no more hazardous to work in radiation areas . . . than it is to perform the same work in nonradiation areas. Sending yearly notices will undoubtedly create undue employee concern and place unnecessary emphasis on radiation even though their exposure is within safe limits."

Mallinckrodt: Objected that provision of the required records to employees "would be useful in damage claims [against the company], even though the licensee had complied fully with the standards."

Bethlehem Steel: Noting that it was dealing with construction and maintenance of nuclear ships, Bethlehem said the rapid turnover characteristic of the shipbuilding and repair industries would make it "almost impossible" to locate potentially exposed individuals within 90 days.

University of California: Sharply asserted that "the excessive additional records required impose undue economic restrictions . . . "

Esso Research & Engineering: Argued that its 400 employees have accumulated a total of only 1.7 rems in the past five years, and protested that the reporting requirement should not be applied to all workers required to wear film badges.

Salt Lake Pipe Line Co. and **Sinclair Research Laboratories:** Proposed that reports to employees be required only when they are exposed to 125 millirems or more in a given quarter.

General Electric and **Pacific Gas & Electric:** The Commission should make clear that employers are not responsible for worker exposure outside working hours. As GE put it, "Although medical exposure is excluded (in the regulations), no provision is made for the employee who has a klystron tube and is building an accelerator as a hobby."

Several companies requested public hearings before any official action was taken. And several suggested that the employee reporting requirements be dropped in favor of a simple requirement that the records be available to employees upon their request.

Cuban Reactor Plans Still Up in Air

Mitchell Engineering–AMF Atomics are still negotiating with Cuba's Bank for Economic and Social Development concerning the 22-Mw (e) boiling-water reactor plant the Bank announced at the Geneva Conference last September it would build in Santa Lucía, Pinar del Rio, in northwest Cuba. However the unsettled political situation there has all but stalled conclusion of a contract for the moment.

Meanwhile NUCLEONICS learns from the Bank that power from the reactor, if built, would be only 0.4 mill short of competitive at startup in 1962, and a predicted 3 mills below conventional power by 1982.

Essentially identical to the Elk River reactor (indirect-cycle boiling-water with superheater), the Cuban unit would have two main differences: oil- instead of coal-fired superheater, and 3%-enriched uranium oxide in stainless steel tubes instead of uranium-thorium clad in zircaloy. It would have an output of 73.1 Mw(th)—14.6 of it from the superheater; 22 Mw(e) gross, 20.5 Mw(e) net; but provision would be made to increase power later to 40 Mw(e). It would deliver 220,000 lb/hr of 600 psig, 825° F steam. It has been offered at a fixed price of $6,385,000 ($311/kw installed) by the Anglo-American team of Mitchell Engineering Ltd. and AMF Atomics. (This compares with $11,453,000 or $558/kw for Elk River.)

Assuming continuation of the steadily rising cost of fuel oil in the Caribbean, a 1.42 mill/kwh decrease over 20 years in nuclear fuel cycle cost, and 80% load factor, and factoring in lower capital costs and fixed charges in Cuba, Prof. Marcelo Alonso of the Bank for Development has made these comparative cost estimates for a conventional plant in Cuba, RAHC-1 (Reactor de Agua Hirvuente de Cuba) and Elk River (in mills/kwh):

		1962		*1982*	
	Elk R.	*RAHC-1*	*Conven.*	*RAHC-1*	*Conven.*
Capital	11.09	4.62	3.34	4.62	3.34
Fuel, nuclear	6.65	4.33	—	2.91	—
Fuel, fossil	1.12	1.44	6.86	1.92	9.27
Personnel	0.75	1.34	1.34	1.34	1.34
Maintenance	0.78	1.20	1.00	1.20	1.00
Total (mills/kwh)	20.39	12.93	12.54	11.99	14.95

Westinghouse Forms Lab to Use Nuclear Power in Space

Westinghouse's big atomic organization invaded outer space last month.

Fulfilling a long-cherished ambition, the pioneering atomic energy firm set up an Astronuclear Laboratory with the aim of developing nuclear power packages in sizeable quantities for both propulsion and secondary (instrument, transmitter, etc.) use aboard space vehicles. To head this audacious project Westinghouse chose its second atomic vice president, Bettis Laboratory director John W. Simpson—the man who carried out the job of building the reactors for *Nautilus* and PWR. Sidney Krasik, Simpson's chief physicist who made the physics calculations for those reactors, will be technical director of the astronuclear laboratory.

Ross Simpson

Establishment of the new project was attended by a widespread change in the organization of Westinghouse's atomic forces. A new atomic power division was established, headed by Simpson. Under him will be both the astronuclear project and the old Westinghouse Atomic Power Department (WAPD) pursuing commercial development of central-station nuclear power, which will continue to be headed by Robert L. Wells. Still separate and distinct will be the Bettis Laboratory, which Westinghouse operates for AEC, where PWR and a series of naval propulsion reactors were developed. Philip N. Ross, reactor engineering manager at Bettis, succeeds Simpson as director of the lab. Both Simpson and Ross will report to Charles H. Weaver, senior atomic vice president who is in charge of all Westinghouse nuclear power activities.

Besides Simpson and Krasik, those named to work on astronuclear power are Walter H. Esselman and Walter Roman, who form the nucleus of an advanced concepts group; metallurgist Donald E. Thomas and reactor engineer Lloyd Kramer, who constitute a materials group, and Frank P. Cotter, executive assistant to Simpson. The astronuclear staff will be housed in quarters now still being sought in suburban Pittsburgh, and will spend much of its first year of existence simply studying and becoming knowledgeable about the space picture, after which it will go after a government contract. It is not expected to grow beyond 20–30 technicians, approximately, during that first year.

Westinghouse Role Seen

Westinghouse's foray into space is the result of a corporate conviction that the need for power there will be a sharply-growing demand, that space power must necessarily be nuclear in origin because of the conditions imposed, and that this supreme technical challenge is an opportunity that Westinghouse as a traditional supplier of power equipment cannot overlook.

Although Westinghouse is by no means the first private company to enter this field, it is certainly the first to go after the broad, across-the-board application of nuclear power for space vehicles. Predecessors in one or another aspect of the field include ACF Industries, components builder and operator of the Rover and Pluto testing area at Jackass Flats, Nev.; Aerojet-General, nuclear rocket fuels; Rocketdyne division of North American Aviation, components; Edgerton, Germeshausen & Grier, rocket testing instrumentation. (Los Alamos Scientific Laboratory is prime contractor on Rover, the nuclear rocket project.)

In addition, there is the SNAP (systems for nuclear auxiliary power) program (NU, Aug. '58, 25; Feb. '59, 30; May, 166), with Martin, Atomics International and Westinghouse working on several approaches to getting power packs into space. These units of course would be far smaller than required for propulsion.

Industry representatives have told Congress that the nuclear rocket can be developed in 4–8 years (William J. Reinhardt, head of technical planning for Reaction Motors division of Thiokol Chemical Co.) or 5–10 years (Thomas F. Dixon, chief engineer of Rocketdyne). At the same time, the nuclear rockets budget of the National Aeronautics and Space Administration is growing apace—$4.5-million in fiscal '59, $8-million in fiscal '60. This acceleration and promise of relatively fast fruition obviously makes the challenge even more attractive.

Demands on a Leader

Internally, for Westinghouse, some changes are foreseen at WAPD, where Simpson's advent cannot help but have an effect on the department's philosophy and ways of doing things. However, while Simpson theoretically will divide his time equally between WAL (Westinghouse Astronuclear Lab) and WAPD, his office will be at the former, and it is likely that the problems and challenges of creating and shaping a brand-new department will inevitably absorb more time and effort than will a going concern.

Observers of the atomic scene interpret the establishment of WAL—or more precisely, the pulling of Simpson, Krasik and Esselman out of Bettis—as conclusive indication that Westinghouse top management now sees the firm's position in the nuclear navy business secure enough to permit it to act in pursuance of its over-all interests with a degree of independence of the czar of the nuclear navy that would have been considered unthinkable earlier. It's known that Westinghouse has been anxious to go to work on nuclear-power-for-space for some time. Vice Admiral H. G. Rickover, chief of the Naval Reactors Branch, assumed an attitude of benevolent indifference to anything Westinghouse wanted to do in space on its own, but naturally resisted removal of key personnel from Bettis. His leverage was reportedly to threaten to award the $18.5-million Natural Circulation Reactor project (*see p 81*) to a competitor. This is borne out by Rickover's statements to Congress. On March 23 he said that NCR "is a leading project at Bettis. Mr. Simpson, Dr. Krasik, and all of the leading physicists and scientists considered it. We have been working on it for a year and a half." But by June 25 he was telling Congress, "Separate studies on this type of reactor are being made by Westinghouse and General Electric. We will decide after a short period of time which has done the best job and decide which one will actually build the prototype."

ROUNDUP

AEC Given $2.65-Billion in New Funds for Fiscal 1960

Congress last month approved $2.65-billion in new funds for the AEC. For operating expenses during the fiscal year ending June 30 (FY '60) AEC was given $2.38-billion in new funds, which, with $133-million carried over from prior years, makes a total of $2.52-billion available in fiscal '60. For plant and equipment, AEC was given $262.5-million which, with carryover of $137.2-million, makes $399.7-million available for fiscal '60.

Operations. The $2.38-billion appropriated was only $28-million less than the $2.41-billion AEC had requested. But, with the carry-over funds, it gives AEC $183-million more than it had in fiscal '59. Hardest hit in the $28-million Congressional cutback was the Isotopes Development Program, which had to take a one-third cut from $6.1 to $4-million. Cuts in other programs were relatively minor.

Construction. AEC was given only $7.5-million less than it requested. Congress ordered a general decrease of $10.5-million in the reactor development program but added $3-million for design and advanced procurement on an advanced reactor using superheat.

1—Operating Budget Up $183-Million

Program	*Fiscal 1959 (millions)*	*Fiscal 1960 (millions)*
Raw materials	702.1	738.0
Special nuclear materials	545.0	563.0
Weapons program	480.0	495.0
Reactor development	342.0	402.4
Physical research	119.0	148.0
Biology and medicine	43.2	49.0
Training, education, and information	13.7	13.5
Isotope development	3.0	4.0
Project Plowshare	2.7	8.0
Community	16.7	15.6
Program administration	49.8	52.0
Security investigation	7.5	7.3
Other costs	6.5	5.6
Selected resources	36.4	50.0
Less revenues applied	−28.7	−31.4
TOTAL OBLIGATIONS	2,339.1	2,522.2
Unobligated balances	+58.2	−133.1
NEW APPROPRIATION	2,397.4	2,389.1

2—1960 Construction Program (millions)

Raw materials		0.1
Special nuclear materials		149.8
Hanford reactor	75.0	
Reactor improvements	16.6	
Prototypes, support	4.0	
Plant modifications	10.0	
General	10.4	
Weapons		34.1
Reactor development		161.9
Modifications and construction, experiments	18.8	
Public power program	25.0	
Organic experiment (II)	6.0	
Shippingport upsize	5.0	
Military and test reactors	31.8	
Support facilities	10.6	
General plant	7.5	
Physical research		64.8
Biology and medicine		3.3
Training, education, etc.		1.0
Isotope development		3.4
High-level radiation lab	1.6	
Isotope process dev. lab	1.5	
Isotope production	0.3	
Communities		2.7
Administrative		0.7
TOTAL NEW OBLIGATIONS		414.7
Unobligated balance		−152.2
APPROPRIATION AUTHORITY		262.5

3—Budget Breakdown, Reactor Development

Program	*Fiscal 1959 (millions)*		*Fiscal 1960 (millions)*	
Civilian power reactors, govt.		75.0		90.1
Pressurized water	17.0		20.6	
Boiling water	4.0		8.2	
Fluid fuel	19.7		7.5	
Fast power breeder	10.2		12.1	
Sodium graphite	6.5		8.7	
Organic moderated	2.8		5.8	
Plutonium recycle	4.8		5.0	
Heavy water	3.7		6.2	
Gas-cooled	5.0		9.5	
Advanced design studies	1.1		2.0	
Experiment fabrication	0		5.0	
Civilian power reactors, coop.		15.2		19.5
Yankee	1.4		0.2	
Fermi	0.3		0.6	
Hallam	5.5		4.2	
Elk River	0		0.1	
Piqua	2.8		0.3	
Chugach	2.2		0	
Northern States	1.3		2.5	
Carolinas-Virginia	1.1		2.6	
East Central/Florida	0.5		2.1	
Boiling water prototype	0		0.8	
Intermediate size reactor	0		1.3	
Unsolicited proposals	0		1.5	
Philadelphia Electric	0		3.1	
Merchant-ship reactors		4.8		5.9
Pressurized-water	1.6		3.2	
Gas-cooled	2.3		1.4	
Boiling-water	0.4		0.7	
Health, safety, etc.	0.3		0.2	
Advanced systems	0.1		0.3	
Army reactors program		9.1		11.0
Package power reactors	1.6		1.4	
Argonne low power reactor	0.6		0.6	
Gas-cooled systems	6.2		6.0	
Compact reactors	0.3		2.0	
General support	0.3		0.5	
Advanced studies	0		0.5	
Design, engineering studies		1.5		5.0
D_2O power reactor	—		2.0	
Prototype tanker reactor	—		1.0	
Remote military reactor	—		0.5	
Superheat reactor	?		0.5	
Other programs	?		1.0	
Euratom program		0		5.0
Systems research, dev.		14.8		17.7
Fuel cycle development		6.0		13.0
Reactor safety		5.5		9.7
Separations systems dev.		5.2		6.0
Radioactive residues management		3.2		4.5
Naval propulsion		86.0		90.0
Airplane propulsion		65.8		68.7
Missile propulsion		21.0		27.9
Satellite power sources		7.5		12.1
Equipment		18.0		19.8

Uncertainty Still Stalks U. S.-Euratom Reactor Program; Only SENN in Clear Position to Meet Oct. 20 Deadline

Like a bird on crippled wing the U. S.-Euratom reactor program fluttered last month toward its first crucial checkpoint—the Oct. 20 deadline for filing construction proposals—with major uncertainties still dogging all but the SENN project. A terse but pointed appraisal by a U. S. industry observer told the story as the deadline neared: "The Euratom situation is all fouled up."

In this vein, it was becoming increasingly clear that the joint program had lost the sense of urgency that had prompted it two years ago. It has, instead, taken on the characteristics of a straight commercial sales campaign, with all the maneuvering, bargaining and disregard for deadlines a sales campaign entails.

On the one hand, the evaporation of the favorable politico-economic climate of the post-Suez era continued to cloud the outlook for nuclear power throughout Western Europe (NU, May '59, 29). On the other hand, each of the electric utility groups that had already declared for new Euratom projects (NU, July '59, 19) faced problems contributing in one way or another to a general slippage of the goal of 600–700-Mw(e) installed capacity by Dec. 31, 1963 and a total of 1,000-Mw by Dec. 31, 1965.

Last month this was the status of the five projects covered by letters of intent filed with the U. S. and Euratom in May:

SENN. Predating the joint U. S.-Euratom arrangement, this 160-Mw(e) reactor has already moved toward a start this fall for completion in late '62. SENN is expected to file a proposal by Oct. 20 to take advantage of the fuel cost and burnup guarantees but capital loans will be by the World Bank.

Franco-Belgian. Electricité de France and its partner, the Belgian utility group Centre et Sud, have no intention of filing a formal proposal by the Oct. 20 deadline. With the obvious aim of maximizing participation by local suppliers, invitations for a 150-Mw(e) reactor went out to French and Belgian firms with U. S. links—rather than to U. S. manufacturers directly—for return to EDF–CES by Oct. 1. An estimated five months will be required to evaluate the bids and a proposal to Euratom is considered likely in April '60. Whether this schedule would permit review by both the U. S.–Euratom selection board and the U. S. Congress in '60 is a question. However, EDF sources said the utilities still intend to meet the Dec. '63 construction deadline. Also, EDF may select a second reactor from the Oct. 1 proposals.

AKS (German). The West German government has refused thus far to clear for subsidy aid the organic-moderated reactor which AKS says it prefers to the pressurized-water proposals of B&W and Westinghouse. However, AKS said it could meet both the Oct. 20 and Dec. '63 deadlines if the OMR concept is approved by Bonn. If not, AKS threatened, it will probably drop its nuclear program indefinitely. Bonn has protested that the OMR is not sufficiently advanced for construction in a 150-Mw size, chiefly because there has not been operating experience with the fuel-elements proposed by Atomics International.

Bewag (West Berlin). Bids from U. S. suppliers for a 150-Mw reactor were due Aug. 15 and the utility is confident it could meet the Oct. 20 deadline unless delays arise in the political and safety areas, where the Bewag project faces its biggest headaches. Both the Berlin Senate and the occupying forces will be consulted before a proposal is made to Euratom and it is conceivable that the Western powers could take seriously an East German complaint on safety. In fact, there is some feeling in Washington that the project should be discouraged whether or not the East Germans protest; Berlin has a population density that raises serious questions about the hazards-feasibility of a 150-Mw reactor.

SEP (Dutch). Dutch utility interests led by Provincie Noord Brabant Electriciteit have scheduled a meeting in September for a possible decision on the type of their 150-Mw reactor. However, the Dutch are leaning away from a Euratom proposal because: 1. fuel burnup and price guarantees by U. S. suppliers are more attractive than those available under the Euratom program (this is true for all Euratom projects, however); and 2. it is felt that capital funds could be raised at interest rates lower than those available from the U. S. Export–Import Bank via Euratom. Other questionable aspects of this project: the utilities are insisting that any reactor they build be competitive with conventional plants; and a Belgian partner may be sought.

Euratom Advancing Briskly on D_2O, Fusion, Propulsion

While uncertainty marks Euratom's power reactor program with the U. S., several other Euratom activities moved along briskly:

- The Euratom Council of Ministers okayed a draft agreement with Canada for cooperation on heavy water reactors (D_2O and/or organic-cooled). At least two D_2O reactors would be built in Europe (sizes uncertain) under the joint program; also, a contingent of European manufacturers will visit Canada this fall.
- Euratom has signed a $9-million research agreement with France for fusion research at Saclay.
- Ready for signature was an agreement with the Dutch KEMA group providing for Euratom participation in a homogeneous reactor experiment near Arnhem.
- Euratom staffers worked out a cooperative agreement in principle with a German group active in nuclear ship propulsion; similar arrangements were being discussed with U. K., other Euratom groups.

National Indemnity Formula Ordered by OEEC Council

A snag in the effort to get ratification of a Western European nuclear liability convention this summer has delayed the convention for several months. However, the delay may be more beneficial than detrimental because it offers the prospect of a stronger and more realistic indemnity program.

The governing council of the 18-nation Organization for European Economic Cooperation returned to its panel a draft convention of last spring (NU, May '59, 34) with orders to work out a formula providing governmental indemnity beyond that required of reactor operators. This would give Western Europe an indemnity posture similar to the U. S., where the Price-Anderson Act provides up to $500-million per nuclear accident (after exhaustion of insurance available commercially). Target date for submitting the new convention to member governments is October.

ROUNDUP

HTGR Contracts Signed after Lengthy, Tough Negotiation

Late last month a small group of men met in AEC's Washington office to affix their signatures to two bulky documents. The occasion: formal signing of contracts on the High Temperature Gas-cooled Reactor sponsored by Philadelphia Electric Co. and the 51 utility members of High Temperature Reactor Development Associates (NU, Dec. '58, 17).

The AEC's contracts with Philadelphia Electric (the reactor will be operated on its grid) and General Dynamics (its General Atomic div. is developing the reactor) are the fruits of months of patient, and at times tough, negotiating.

In some respects, the contract talks were typical of what other companies or groups hoping to do business under the Cooperative Reactor Demonstration Program can expect. In one significant respect, however, the negotiations were precedent-setting. That is, the Joint Committee on Atomic Energy was a vigorous AEC partner throughout the talks and was responsible for several major provisions (including the handling of patent rights and obligation to build). In no other cooperative arrangement, AEC officials concede, has JCAE had so much influence.

Acknowledging this, an AEC official pointed out that the "novel" political aspects of the project left AEC with the feeling that "it could hardly take a cavalier attitude with the Joint Committee."

In late November, PE and a group of 51 utilities—banded together as the High Temperature Reactor Development Associates, Inc.—submitted a formal proposal to develop, build and operate a 30–40-Mw(e) helium-cooled reactor system of the type conceived by GD's General Atomics div. PE was the formal sponsor.

The proposal was backed up with a suitcase-full of interlocking contracts (*see diagram*).

Philadelphia Electric agreed to put up $8-million of the total estimated construction cost of $24.5-million. HTRDA would provide the rest.

PE and HTRDA had signed a $24.5-million fixed-price contract with the Bechtel Corp. for design and construction of the plant, and Bechtel in turn had negotiated a fixed-price contract with General Atomic for the nuclear portion of the plant, and another with Westinghouse for the conventional turbines and electrical equipment.

Philadelphia Electric, which itself requested waiver of use charges on fuel up to $2-million, conditioned its proposal to build and operate the plant on AEC agreement to pay up to $14.5-million in support of research and Development work to be carried out by GA.

The project required AEC contracts with only two of the parties—General Dynamics for research-development work, and Philadelphia Electric, which took full responsibility for designing, developing and building the plant and operating it for five years as part of its system.

The HTGR proposal ran into trouble at the outset when it was filed in November.

At the staff level, AEC's conclusion was that the reactor would require not only development, but invention. Democrats on JCAE saw the proposal as nothing more than an attempt to head off government construction of a gas-cooled reactor along the lines of the Kaiser-ACF design.

The selection board, meeting in December, generally favored the proposal. But the general counsel's office recommended against acceptance on grounds it was not wholly responsive to the AEC invitation and the legislative authorization. Among other things, the sponsors did not contemplate completion of construction until well after the Dec. 31, 1962, deadline imposed in the invitation. Completion target is now Oct. 1, 1963.

Nevertheless, champions of the high-temperature concept convinced AEC it was well worth exploring—offering, as it does, a possible leapfrog advance in reactor technology.

As a result, a compromise was worked out with key JCAE members whereby AEC will go ahead and build the less advanced Kaiser-ACF reactor, and offer research-development support under the demonstration program for the HTGR project. But special legislative authorization was necessary.

Negotiations began in mid-January on the joint letter of understanding, which was signed and submitted to the JCAE a month later. Then, after the committee's annual authorization hearings were concluded, formal negotiations on the final contracts began and continued until the middle of June.

THE CAST

The Commission's negotiating position, in broad terms, was laid down by the AEC commissioners. The influence of JCAE was strongly felt, although it took no direct part in the talks. However, the actual chore of hammering out two detailed contracts was in the hands of about 20 men who met at least a dozen times.

John Erlewine, chief of the contracts branch, Reactor Development div., headed AEC's negotiating team. He was backed up by Joseph F. Hennessey and W. D. English from the general counsel's office, E. C. Woloham of the finance office and Don Groelsama, an expert on gas-cooled technology.

General Atomics' five-man team was led by Henry B. Fry. Chief negotiator for Philadelphia Electric was L. R. Gaty, aided by Counsel Vincent McDevitt and two other assistants. Francis E. Drake, Jr., sat in for HTRDA; M. Van Hoesen for Bechtel.

The first step was preparation by the AEC staff of draft contracts, following the lines laid down in the already agreed-upon letter of understanding. Then, after the parties had a chance to analyze them, contract talks began.

"We went through the negotiating draft line by line," recalls Erlewine, "and discussed those points where objections were raised or changes requested. Everybody went home while our staff made another draft. Then we met again and went through another round of give and take."

In all, the negotiators gathered around the long, polished conference table on about six separate occasions in this phase of the contract talks.

THE PROBLEMS

The first clash of viewpoints came in the first round of negotiations in January—and it revolved around how much voice AEC would have in the research-development work by General Atomic.

As an AEC official explains, "General Atomic is obligated to carry out the research-development program at a fixed ceiling cost and on a promised schedule. They have to meet this obligation even it it ends up costing considerably more than the $14.5-million maximum the Commission will put up. So it's natural that they wanted pretty full control over the program.

"But AEC has to look at this from a different view-

point. We're supporting this work, after all, only in order to get answers that will help everybody in the business and advance the state of the art. So we have to have the final say."

The Commission had its way. General Atomic must get advance AEC approval each year for the research-development scheduled for the following 12 months.

However, GA won a point, too. In case of serious disagreement over the program, the parties will choose a competent board of outside experts to arbitrate.

Patents. A disagreement over patents took longer to work out. In fact, it was not completely settled until June. And it is understood that high-level talks between AEC Chairman John McCone and General Dynamics President Frank Pace took place on this point, just as they did on the research-development issue.

GA had spent more than $1.5-million of its own funds on research-development of the advanced gas-cooled reactor before the Philadelphia Electric proposal was ever submitted to AEC. Seventeen patent applications had been made as a result. GA wanted to hold title to them, although the company did not dispute that future patents developed in the course of the government-supported project would clearly belong to AEC. However, AEC laid down its view that a company, in such a case, can hold nuclear patents only if they were reduced to practice before the contract takes effect, instead of being mere conceptions.

On this point, AEC was adamant and GA ended by giving up claim to all 17 patents.

How does GA feel about the contract? "We have no complaints about the way this contract turned out," a company official said. "It appears to give us the flexibility we wanted."

Philadelphia Electric. The PE negotiators had mixed success, too. On patents, the company preserved the right of its employees to any nonnuclear patents they developed on the project. But on the contract itself, there is a "disputes" provision under which any contract dispute will be ruled on first by an AEC contracts officer —and if the utility refuses to accept his decision, an AEC hearing examiner has the final say as to a finding of fact.

An AEC official said it was natural that a company unaccustomed to dealing with government would bridle at such a provision. And PE did.

"It seems to give all the powers of an umpire to the other team—that is, the AEC," it was conceded by the AEC official.

AEC points out that this procedure is almost standard in government contracts, although admittedly it is not included in all cases. For example, it was left out of the East Central/Florida West Coast contract, where the companies are splitting research-development costs 50-50 with the government (NU, '59, 25).

Obligation to Build. AEC is confident it has adequate guarantees on one point that especially worried JCAE—the obligation of the parties to go through with building the project and eventually inserting a graphite-clad core.

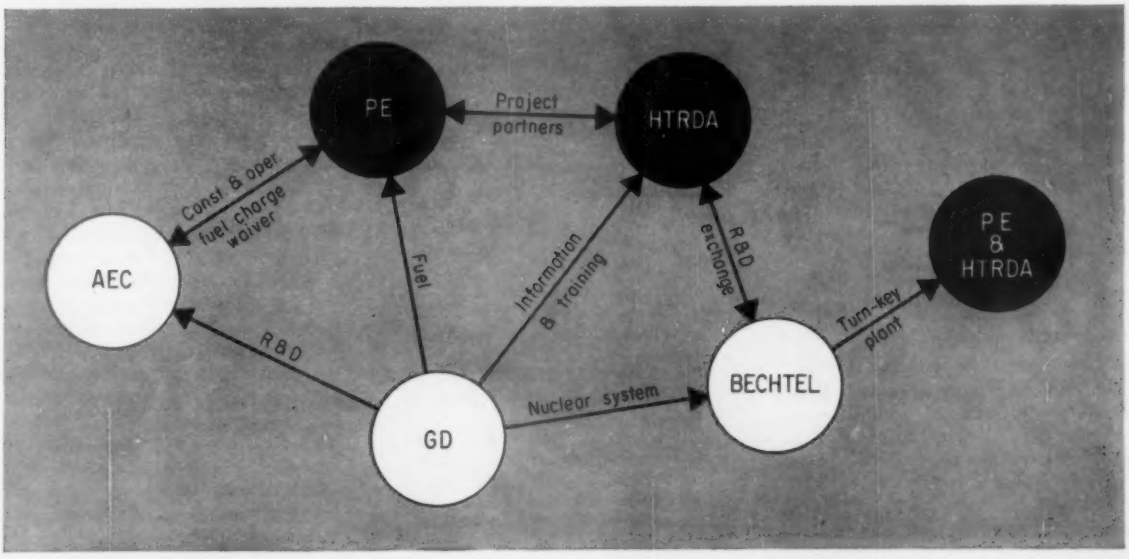
An AEC official made it clear that PE has a flat obligation to build the described plant, subject to a specific escape provision. And, although it is recognized that the first-core may be metal-clad, the "described" 40-Mw plant calls for graphite cladding.

Development of usable graphite-clad elements is a major goal of the program. Thus a breakdown of this effort would be the only justification for failure to install the graphite-clad core, in AEC's view.

The contract's escape provision implements the Congressional mandate that, in case the companies unilaterally decide to abandon the project, they must reimburse AEC for its research-development expenditures, minus credits for whatever patents, property or other value have accrued to AEC (NU, July '59, 19). The provision does not apply if AEC agrees to abandonment or if abandonment involves reasons beyond the control of either party.

All in all, AEC officials believe they have negotiated two sound and reasonable contracts. Although some industry kibitzers are inclined to think the terms are tougher than usual, the companies involved profess not to think so. However, it is clear that PE and GA were bludgeoned by the AEC-JCAE coalition into accepting patent and other concessions in order to get the project moving.

Relationship of Participants in HTGR Project



Aircraft Program Being Reoriented Toward Indirect Cycle; Still No Flight Target-Date, Hearings Show

The atomic airplane story still "ends in a fishtail," as the French say—i.e., it's unresolved, aimless, pointing in opposite directions.

This despite a dramatic hearing at which the behind-the-scenes issues in the long-smoldering controversy were dragged out into the spotlight by Rep. Melvin Price (D-Ill.), chairman of the Joint Committee's research and development subcommittee. During an exhaustive—and exhausting (6½-hour) one-day session July 23, much light was shed on long-hidden details of program history and political infighting, but little new emerged on the issues underlying why, after 14 years and $840.2-million, we still have no target date for getting a plane up.

Basically, the crux of the problem still appears the same as it always did: indecision in the Administration. Or as it has often been put: lack of a Rickover to stake out a philosophy and a goal for the program and then keep driving toward it, tolerating no deviations or hesitations.

Dr. Herbert F. York, director of Defense Research and Engineering, reported the Administration decision:

"Program objectives for the immediate future should be:

"A. Continue the development of only such reactors and power plants as would be suitable for militarily useful nuclear flight.

"B. Increase the effort on the indirect-cycle program so as to determine its potentialities at an earlier date than previously contemplated.

"C. Defer initiation of a specific flight program until (1) one of the advanced power plants is established as feasible and potentially useful, and (2) a flight program can be instituted without seriously interfering with the development of militarily useful power plants."

York's testimony came under severe Republican as well as Democratic fire as running counter to best technical opinion. It was admitted the Administration was motivated by budget considerations, shying away from the extra expenditure now that a flight test would require.

Up Pratt & Whitney

The testimony confirmed what had previously been reported: Pratt & Whitney and its indirect-cycle system, long in the shadow of General Electric's direct-cycle engine (fiscal 1959 funding split: GE, $103-million; P&W, $17-million), is now moving into the forefront. An Administration determination says "the indirect cycle system, while intrinsically more complicated and somewhat further off in possible availability, is also intrinsically more useful." (*For comparative sketches of direct, indirect cycle, see* NU, Aug. '56, 75.) P&W's dollar share is going up to $23-million in fiscal '60, $35-million in '61. A P&W supporter is the Navy: the indirect-cycle engine has been the Navy's choice and object of its studies, being better suited to the Navy need for low-power—60–100 Mw(th)—use. "We do not believe in a direct air cycle," says Navy research chief Adm. John T. Hayward. "It has the divided shield instead of the unit shield. It exposes all of our equipment to radiation. We just cannot live with it."

Also, ANP boss Maj. Gen. Donald J. Keirn reported that recent progress on indirect cycle is "most promising and a nuclear propulsion system for a B-70 type aircraft appears possible." P&W is now planning to start a reactor experiment on an advanced system, for completion in 3–4 years.

The word "advanced" here is important. For both the direct cycle and indirect cycle, the hearing revealed, there is a design using "available materials," and there are designs intending to use certain "advanced materials" which designs "show considerable theoretical promise but have not yet been shown experimentally to work under the necessary environmental conditions."

The GE direct-cycle early-flight plane that many thought was on the verge of being ordered this summer, only to be turned down by the Administration, would have been powered by an "available materials" plant. This is the basis for the Administration position that such a plane would not only be militarily useless, but would have little or no growth potential. The Administration contends that awaiting development of the advanced materials is the faster way to achieve a truly useful nuclear power plant. GE on the contrary says, "We believe actual flight testing is the *only* means by which it is possible to obtain the full range of systems information required, such as nuclear and aeromechanical data. . . . The capability is now available, and the next stage—flight testing—must be gone through if this program is to ultimately succeed."

State of the Art at GE

D. R. Shoults, GE's ANP dept. general manager, reported shielding principles and control system stability are now established; the Idaho reactor experiments have verified "both theoretical reactor physics and full-scale powerplant feasibility"; materials development for both fuel elements and moderators is now able to meet initial powerplant flight test requirements; and reactor performance technology "has progressed to the stage where reactor power is effectively flattened to the point where the local power level does not exceed the average by more than 7–8%." GE has spent $457-million of the total $840-million spent on ANP thus far.

The Air Force wanted the plane GE could build now, for its CAMAL mission (Continuously Airborne, Missile-Launching and Low-level Penetration system). It proposed construction of two experimental planes with the dual purpose of flight-testing the powerplant and serving as a CAMAL prototype.

Both AEC chief McCone and Keirn favored construction of the early-flight plane. Keirn denied that it would be militarily useless.

Keirn, incidentally, was to retire Aug. 31. Brig. Gen. Irving L. Branch will take over at least the Air Force part of Keirn's two-hat job, but it is not yet known whether he will also have his AEC post. The Defense Dept. and AEC are studying plans to reorganize ANP management, with one possibility being appointment of one company to manage ANP.

Navy Continues Work On Indirect-Cycle A-Seaplane

The Navy has awarded the Martin Co. a $127,000 research and development contract on airframe designs for a nuclear turboprop seaplane for anti-submarine warfare. This is part of the Navy's program aimed at putting a nuclear seaplane in the air "by 1964."

The Navy, which has spent $12.4-million on nuclear seaplane studies in 1955–59, will spend $2-million in fiscal 1960, plans to spend $4–5-million in fiscal '61.

Reactor News

SRE HAS FUEL-ELEMENT PROBLEM

The Sodium Reactor Experiment has been shut down since July 26. Following a special run at low power conducted to reduce abnormal temperature distribution, half a dozen fuel elements proved, unexpectedly, to be severely damaged: no melting, but individual rods separated near their centers. Cause is not known; one theory is that following a leak of tetralin, used to cool certain components, some tetralin may have remained in and blocked some channels. Involved are elements of the first core, now near end of its life; the second core has been ready for loading for some time.

PIQUA BREAKS GROUND

Three years and 5½ months after it proposed building a 12.5-Mw(e) organic moderated nuclear power plant, the City of Piqua, O., finally broke ground in July for its reactor. Atomics International designed and will build the $7.7-million reactor, part of a $14.1-million project. Plans are to go critical in July 1961, start full-power operation in October 1961.

HWCTR GROWING

A 5-ft thick concrete base slab has been completed at AEC's Savannah River for the 70-ft-dia containment shell that will house the Heavy Water Components Test Reactor. The $8-million reactor, being built for AEC by the du Pont Co., is to start operation by January 1961. The base slab, 52 ft below grade, will support a 125-ft high shell, which will be unusual in that its underground wall will be of post-tensioned concrete 18-in. thick, and its above-grade wall of carbon steel plate (¾-in. in the cylindrical wall section, ⅜-in. thick in the hemispherical dome). Heavy water moderated and cooled, HWCTR will have a 100-ton pressure vessel 7 ft dia, 32 ft high. It is being built with two loop systems costing an additional $1.3-million. It will be used for operational tests on fuel elements and critical components, in a study on feasibility and economics of D_2O-moderated power reactors.

TWO CIVIL-FUEL REPROCESS PLANTS BEGUN

AEC has put in motion two projects to provide chemical reprocessing capacity to handle spent fuel elements from the civilian power reactors now under construction—one at Oak Ridge, one at Hanford. The former is already under way, with Vitro doing detailed design; the latter is in preliminary design stage (now being completed by General Electric) with Vitro negotiating to begin detailed design shortly. In both cases, existing solvent-extraction facilities will be used—Redox at Hanford, Thorex and Metal Recovery Plant at Oak Ridge—with new facilities being added to adapt them to handle power-reactor elements, such as transfer and decontamination facilities for shipment casks and provision for fuel-element storage, mechanical processing (cropping end fittings, decladding where necessary, etc.) and dissolving. Oak Ridge will handle thorium-bearing fuel from the Con Edison and Elk River plants, but will have capacity and flexibility to take fuel elements from almost any U. S. reactor, and will also get for reprocessing most of the foreign research reactor fuels, *Savannah*, the Oak Ridge gas cooled reactor, Florida West Coast, the SRE first core, and the axial blanket from the Fermi reactor (a large fluoride volatility processing plant will also be modified to take parts of *Nautilus* and *Nautilus* prototype cores).

The expanded Thorex–Metal-Recovery plant, amounting to a small multi-purpose plant, will be completed in late 1961, will have a daily capacity of 300 kg of low-enrichment (to 5%) U, 7–8 kg fully enriched U, or 200 kg Th. The modifications will cost $4.7-million. Hanford will get 50–150 tons/yr of low-enrichment (to 5%) U likewise of highly-diversified types: alloy or oxide, Al-, Zr- or stainless-clad, in many shapes and sizes. Hanford modifications will cost $6-million, will be completed early in 1961. This project is being carried out by General Electric under the existing AEC-GE contract for operation of Hanford. Incidentally, AEC has scheduled a two-day symposium for management and technical personnel on reprocessing, Oct. 20–21 at Hanford.

DOW GETS PYROPROCESSING JOB

AEC has awarded Dow Chemical Co. a $216,000 contract for research in pyroprocessing spent fuel. Robert J. Teitel, chief of reactor metallurgy, is project manager.

EPITHERMAL REACTOR INTO SECOND PHASE

Atomics International will carry out critical experiments to help determine design of its Advanced Epithermal Thorium Reactor, subject of a $5-million, four-year study for Southwest Atomic Energy Associates (NU, Oct. '57, 21). To be carried out in a split-halves honeycomb type of critical assembly, the mock-up experiments will study effects of reactor materials on the chain reaction. They constitute the second phase of the project. First phase, completed in June, included conceptual design and analytical studies of possible core and blanket configurations to determine engineering problems, performance requirements and economic potential. AETR would be sodium cooled, Th-U alloy fueled, beryllium or graphite moderated, and would produce 360 Mw(e).

GE'S NTR EXPECTED BACK ON LINE

AEC has announced it plans to permit resumption of operation of General Electric's Nuclear Test Reactor, a small (30-kw) light-water-moderated and -cooled, graphite-reflected research reactor at Vallecitos. This unit had started operating in October 1957, but after several months GE discovered, AEC said, that "the reel assembly supporting the fuel elements in the core was damaged, the coarse control rods were found to be worth less than design value, and biological shielding for a 30-kw power level was shown to be inadequate." The facility has now been rebuilt. NTR will be used to measure neutron absorption in structural material samples, to calibrate foils for critical experiments, and for neutron-flux experiments.

2D A1W CRITICAL; AVR CONTRACT SIGNED

The B plant of the A1W large ship reactor prototype in Idaho has gone critical, NUCLEONICS learned; the A plant has been operating almost a year (NU, Nov. '58, 28) . . . At press close, word came from Bonn that the long-awaited construction contract for the AVR pebble-bed reactor at Jülich had been signed (NU, Aug. '58, 26).

IDAHO, HANFORD CONSTRUCTION

A busy month for facility expansion in the West saw these contracts bid or awarded: a plutonium recovery facility, a fuel cladding facility and a critical mass laboratory at Hanford; and a technical service lab, technical support building, and instrumentation systems at the Aircraft Nuclear Propulsion area of the Idaho station.

ROUNDUP

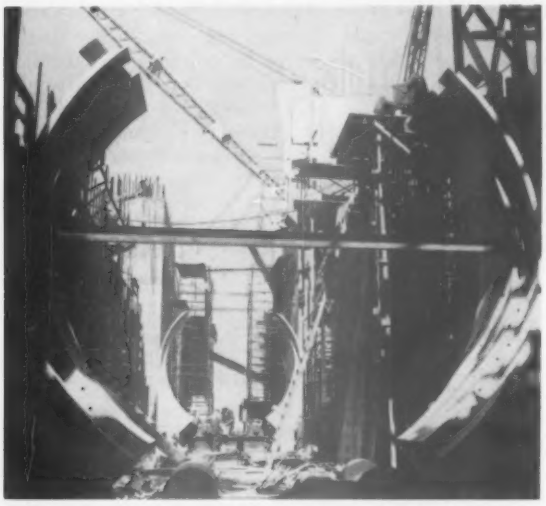
World News

India to Buy Big Power Reactor Abroad

India's long-awaited (NU, Feb. '57, R11) first power reactor has finally been scheduled, and the world's hungry reactor manufacturers will have a chance to bid on it. Indian AEC chairman Homi J. Bhabha announced that a 250-Mw(e) nuclear power plant budgeted for $90-million will be set up on the coast close to Bombay for 1964 completion. It will not be designed in India: world-wide bidding is to be invited by year's end. Furthermore two more such units are to be built in India's third 5-year plan ending in 1966—one in Rajasthan state, northwest India, the other in south India. Bhabha claimed power at the new Bombay plant would cost 8 mills/kwh at the outset, 4 mills after five years.

Progress on Canada's NPD

The 20-Mw(e) Nuclear Power Demonstration reactor now building between Rolphton and Des Joachims, Ont., begins to show outlines of its unusual configuration with



a horizontal reactor vessel (compare sketch NU, Sept. '58, 76). The plant is to be completed late in 1960.

Dungeness, Radiowaste Dump Sites Set

Britain's Ministry of Power has approved construction of the proposed "Kent A" nuclear power plant at Dungeness (NU, July '58, 26). The site may become the world's largest nuclear power station, as the first plant, 500–550 Mw(e), may be followed after 1962 by Kent B and C. Even more significantly, NUCLEONICS learned in London that Kent A may be the first of the AGR beryllium-clad type of gas-cooled reactor. Only less than a year ago it was still thought that Dungeness, like Trawsfynydd before and Sizewell after it, would be improved Bradwell-Berkeley (second-generation Calder) types with the first large-scale AGR type coming only after Sizewell. . . . AEA is taking over a 250-acre site near the Windscale plutonium plant to store radioactive wastes. First to be stored will be mildly-contaminated rubble from abandoned parts of Windscale reactors after the October 1957 accident (NU, Nov. '57, 26, 130).

Salvetti Resigns as Euratom Gets Ispra

Carlo Salvetti, director of Italy's Center of Nuclear Studies (which built the Ispra research complex), resigned to protest Italy's action turning Ispra over to Euratom. His resignation was reported July 23 by the Italian news agency ANSA, even as the accord was being hailed in Italy as a step toward European unity. However it had been under fire, chiefly by Italian left-wingers who oppose Euratom on principle, on the ground it was a giveaway of a $20-million investment. The previous day the Italian Government and the Euratom Commission had signed the agreement leasing Ispra to Euratom for 99 years (NU, Aug. '59, 21).

IAEA Leases Lab Site; Top Staff Change

The International Atomic Energy Agency has taken a 99-year lease on a 14-acre site for its functional laboratory (NU, June '59, 25) at Seibersdorf, 19 mi E of Vienna. The land is leased by the Austrian Company for Atomic Energy Studies (SGAE), which is building Austria's national atomic labs adjoining; the two labs are expected to collaborate closely . . . George E. Roth of New Zealand, director of the Dominion X-Ray and Radium Laboratory there, succeeds Yoshio Fujioka of Japan as director of IAEA's Division of Isotopes.

New Reactors: U. K., Germany, Poland

Britain's first privately-owned reactor, a "Merlin" 5-Mw pool research reactor built by Associated Electrical Industries at Aldermaston, went critical July 16. . . . Germany's electrical-equipment firm AEG will build a 10-watt research reactor near the 15-Mw(e) power reactor it is building at Kahl for RWE. . . . Poland, which has one Russian-supplied pool reactor, plans to build a second research reactor earmarked for radiation chemistry.

British Briefs

Sir Roger Makins, Ambassador to Washington 1953–56, will succeed Lord Plowden as chairman of the U. K. Atomic Energy Authority Jan. 1. He once headed an advisory body to the government on atomic energy policy. Sir Roger, 55, is currently a joint permanent secretary to the British Treasury. Lord Plowden will be chairman of British Aluminium Ltd. . . . Rolls Royce is building a developmental plant in Derbyshire to produce the fuel elements for the Royal Navy's second nuclear submarine, which is to have a British-designed pressurized-water reactor. Rolls Royce is also making the S5W-type elements for the Westinghouse-supplied reactor for HMS *Dreadnought*, Britain's first A-sub (NU, June '59, 30). The British-designed fuel will be tested in the land-based prototype being built at Dounreay. . . . A new British firm, Consolidated Beryllium, Ltd., was founded last month, equally owned by Beryllium Corp. of Reading, Pa., and Imperial Smelting Corp. Ltd. of London. It will be managed by the latter, and will produce nuclear-grade Be for sale to fabricators both in England and in Europe.

Year-End Accounting in Britain

AEA estimates for fiscal 1960 were £92,433,010 ($258-million), a decrease of £13.4-million from fiscal 1959, according to the Authority's fifth annual report. Other highlights included: the Dounreay fast reactor blanket elements have been loaded and NaK coolant charged and the reactor "should begin a period of low-power testing during the summer of 1959"; the plutonium-fueled zero-energy fast reactor Zephyr at Harwell was dismantled; the gaseous diffusion plant at Capenhurst was "extended by addition of units of large size."

News in Brief

AEC May Delay Safety-Criteria Effort

AEC's Division of Licensing and Regulation is having second thoughts about proceeding at this time with its program for establishing reactor-safety criteria. The negative industry response to the first step—proposed ground-rules for site selection (NU, Aug. '59, 21)—has AEC wondering whether the entire effort might best be delayed for several years. The hope had been—in order to simplify the licensing-application problems of prospective power and test reactor operators—to define simple site criteria, then do the same for other reactor-safety factors (containment, design, etc.). No final AEC decision on the program will be made until completion of review of industry comments on the site proposal.

Floberg Urges More Realism in Cost Estimating

AEC Commissioner John F. Floberg has called on the reactor industry to take a more realistic attitude toward nuclear-power costs. In a little-publicized speech to the American Nuclear Society in June, Floberg declared that "underestimates of three or four years ago have done as much as technical difficulties, if not more . . . to discourage a larger number of privately-financed power reactor projects." He revealed that AEC is now attempting to establish a set of capital-cost standards to show "what goes into the cost of a reactor" and that Hanford, Oak Ridge and Argonne have undertaken studies "on the real commercial value" of plutonium, U^{233} and U^{235}. Meanwhile, other AEC sources said that AEC informally sounded out some industry people last spring on the feasibility of selling enriched U domestically (rather than leasing as is now required by law). The tentative proposal brought a mixed reaction and may be pursued at a meeting with industry this fall.

U Mills Ordered to Improve Waste Practices

Collaborating in unprecedented fashion, AEC and the U. S. Public Health Service are cracking down on uranium mill operators accused of permitting excessive radioactive wastes to reach neighboring rivers. AEC has a responsibility for policing its licensees; USPHS has a responsibility for discouraging pollution of interstate water. In the first case involving direct action by both agencies, the Durango, Colo., mill of Vanadium Corp. of America has agreed (with USPHS) and been ordered (by AEC) to take steps to prevent radium from reaching the Animas River, which flows from Colorado into New Mexico. AEC has also ordered five other mills to tighten up their waste-disposal practices or face license revocation.

16 New IDP Contracts Announced by AEC

AEC's Office of Isotopes Development last month announced the award of 16 additional contracts under the Isotopes Development Program (NU, Aug. '59, 27). The list:

Armour Research Foundation (3): To study the radiation physics of cesium-137 irradiators, $45,500; to demonstrate a gauging system to measure mass and density as a function of gamma or x-ray attenuation, $29,856; and to develop beta-emitting x-ray sources, $29,900.

Bituminous Coal Research: Isotope potential in the coal industry, $40,000.

CEM Group (Emerson Radio): Commercial potential of certain isotopes and processes, $50,000.

Engelhard Industries: Effects of ionizing radiation on catalytic activity of platinum, $50,000.

Georgia Tech.: Support for a variety of research and development activities, $100,000.

William H. Johnson Laboratories: Basic research-development studies on high-level radiation, $45,200.

Lockheed: Develop a gauging system for detecting boiler and heat exchanger defects, $27,600.

National Canners Assn.: Eliminating detergent carryover in washed foods, $38,800.

Radiation Applications: Separating gross fission products (emphasis on foam separation), $7,000.

Stanford Research Institute(2): Training journeyman personnel in isotope-using industries, $40,000; and analyzing isotope uses in agriculture, $23,000.

Technical Research Group: Production of pure silicon via radiation-induced decomposition of silicon compounds, $35,000.

Tracerlab: Radiochemical methods for detecting and analyzing non-radioactive gases and studying clathrate compounds (*see p. 130*), $44,800.

Westinghouse: Develop transparent polyethylene production via radiation, $23,500.

AEC Asks Formal Reports on Fissionable Material

AEC has proposed a system of semiannual reports by licensees possessing special nuclear material; accounting reports are presently made by licensees only upon specific AEC request. Under a proposed regulation published last month, reports would be due within 30 days after Dec. 31 and June 30 each year. Industry was asked to comment on the proposal by Oct. 5.

Morale Restored at Reactor Development Div.?

Officials of AEC's Reactor Development div. said last month they thought they were over the worst of a morale problem which had been primarily responsible for the loss of 10–15 members of the division's technical staff. Reasons offered for an admitted discontent: **1.** normal reaction to a change of leadership (Frank Pittman was named director of the division in October to succeed W. Kenneth Davis: NU, Nov. '58, 22); and **2.** the decentralization policy adopted by Pittman (NU, Aug. '59, 26), which is resulting in removal of some authority from division branches for eventual assignment to operations offices.

Radiation Brjefs

AEC has reduced its price for **iodine-131** by 20–25%. New price list (with old prices in parentheses): 0–199 millicuries, 40¢/mc (50¢); 200–499 mc, 35¢/mc (50¢); and 500 mc or more, 30¢/mc (40¢) . . . "Fido" (Fallout Intensity Detector Oscillator) has been developed by **Controls for Radiation** for possible use in civil defense and the nucleonics industry. The battery-powered unit, smaller than a cigarette package, emits an audible signal which increases as radiation intensity rises above 0.2 r/hr; its solid state sensing element responds to radiation at dose rates up to 5,000 r/hr. Estimated price: $10–$15 . . . **A total-body irradiation facility** is being added to the Medical Division Hospital at Oak Ridge; some 4,000 curies cesium-137, divided into eight sources, will be used for: **1.** wider research on the therapeutic value of radiation treatment for acute leukemia, aplastic anemia and other diseases; and **2.** further evaluation of bone marrow transplantation in treating massive-radiation-dose cases. . . . An **Isotopes and Radiation Applications div.** of the American Nuclear Society is being formed, subject to approval by the board of directors; a petition for board approval was being drawn up by a special five-man committee last month.

LATE & MISCELLANEOUS

AEC for Th-Breeders . . .

In a reorientation of its fluid fuel reactor program—indeed as a replacement for it—AEC has announced a long-range program to develop effective thermal breeders (goal: 15-year doubling time). AEC says it has no present plans for building a machine, but will do unhurried basic research for an undetermined period. Oak Ridge is drawing up a report for AEC on what such a thermal breeding program should be like. The Liquid Metal Fueled Reactor Experiment is already phased out at Brookhaven and Babcock & Wilcox; Oak Ridge's Homogeneous Reactor Experiment 2 is expected to run at least one more year.

. . . for Process Heat . . .

AEC and the Interior Dept. are preparing to issue an invitation to industry to build a 40-Mw(th) process-heat reactor. AEC wants a unit to show the feasibility of nuclear process heat for industry generally, Interior wants a reactor strictly for treating 1-million gal/day saline water; the reactor will be designed to do both. It will deliver 380° F steam, initially at 13 psi, working up, it's hoped, to 175 psi. Although a pressurized water type, it will use carbon steel.

. . . and for Small PWR

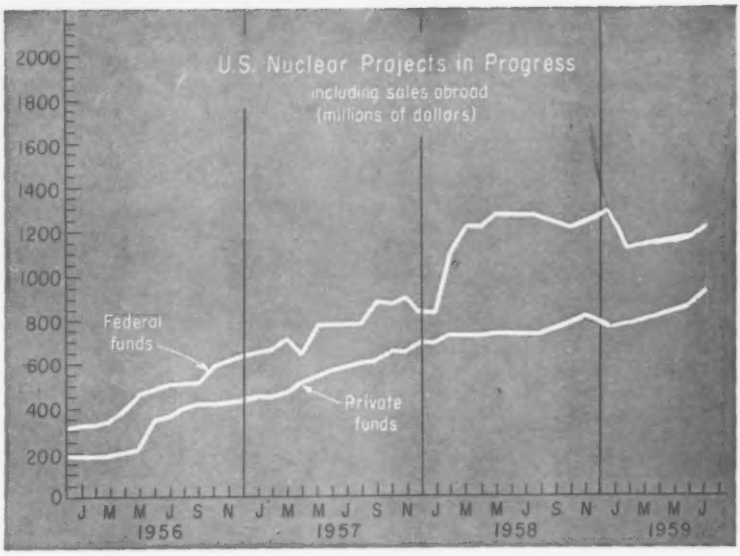
Nov. 16 is the deadline on AEC's invitation to rural co-ops and publicly-owned utilities to submit proposals to build a 16.5-Mw(e) pressurized water plant (22 Mw if a superheater is added) for May 1962 completion. Project goal: to "make a significant contribution to achievement of economic electric power in a small size plant."

***Dreadnought* Unit at Westinghouse**

Westinghouse has set up a Special Atomic Project dept. under William R. Ellis to procure the *Skipjack*-type reactor for Britain's first nuclear submarine, H.M.S. *Dreadnought*, and to train British engineers in its design and construction. The department will comprise about 60 engineering, purchasing and manufacturing control personnel.

Williams Confirmed

The Senate, without discussion—much less controversy, confirmed John H. Williams as a member of AEC, succeeding Willard F. Libby.



NUCLEONICS Statistics of the Month

	Latest month	Month ago	Year ago
Nuclear Contracts *—			
Contracts awarded for federal projects ($10³)	37,409	11,276	10,501
Proposed construction, privately-owned ($10³)	0	0	0
Contracts awarded, private work ($10³)	1,791	30,000	1,000
Backlog of private projects ($10³)	285,000	285,000	249,549
Isotope Use †—			
Applications for isotope use	575	700	718
Cumulative total of isotope users	5,077	5,017	3,929
ORNL shipments (curies)	8,743	25,304	58,119
Public and private export shipments	302	85	252
Employment †—			
AEC employment	6,785	6,649	7,021
Construction and design contractors' employment	9,878	9,756	10,662
Total operating contractors employment	105,195	104,116	103,290
Production workers	51,930	51,555	51,222
Research and development employees	48,423	47,390	45,633
Miscellaneous workers	4,842	5,171	6,435

U. S.-built Reactors ‡—

	Operating	Building	Contracted
Power, domestic	1	7	7
Power, for export	0	3	2
Power experiments and pilot plants	6	5	0
Military and naval	10	44	5
Research and test, domestic	58	21	48
Research and test, for export	14	14	9
Total	89	94	71

Foreign-built Reactors ‡—

Power, domestic	10	28	17
Power, for export	0	2	1
Research and test, domestic	34	11	11
Research and test, for export	8	6	0
Total	52	47	29

* From *Construction Daily*, a McGraw-Hill periodical † From AEC ‡ NUCLEONICS figures

RCLiac 128 USED ABOARD ATOMIC SUBMARINE TRITON

Compact Reliability for Nuclear Fleet

General Electric scientists and engineers from the Atomic Energy Commission's Knolls Atomic Power Laboratory selected the transistorized RCLiac 128 Channel Scaler-Analyzer for use aboard the world's largest atomic submarine because of its reliability, compact size, low power consumption and ability to measure decay of short-lived nuclides. The RCLiac 128 was used aboard the atomic submarine Triton to perform short half-life studies and other tests. The RCL 256 Channel vacuum tube analyzer had been used in earlier dockside tests.

RCL instruments are found wherever reliability is important. The transistorized RCLiac 128 has proved particularly useful wherever space is at a premium. RCL vacuum tube analyzers are frequently used in larger quarters. RCL now offers four multi-channel vacuum tube analyzers: RCL 256, RCL 512, RCL 1024, and RCL 2048. Specifications are available for each model.

For complete information on RCL's transistorized and vacuum tube analyzers, write Dept. 199.

Rugged, compact RCLiac 128 performs both analyzing and scaling operations.

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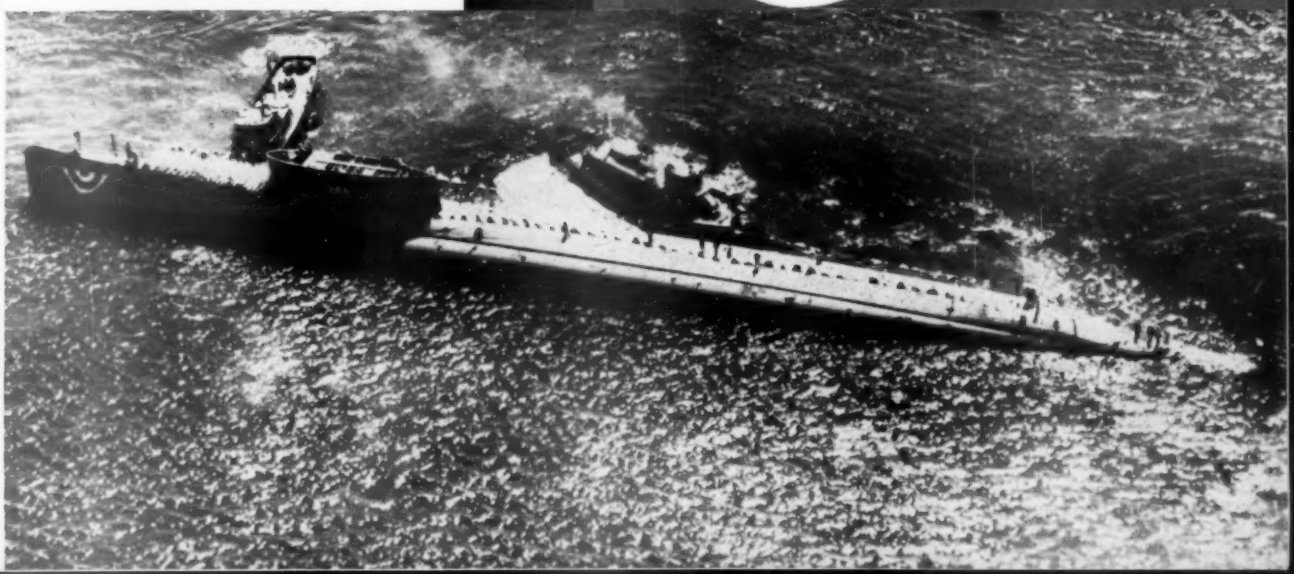


Launching of Atomic Submarine Triton

53 ozs.
(.5" lead protection)

53 lbs.
(2.5" lead protection)

53 tons
(12.0" lead protection)

Lead shielding...unlimited

Virtually the only limitations on the size, weight and complexities of lead shielding produced by National Lead are set by customers... not by our facilities, equipment and people. National Lead has the resources and the resourcefulness to produce all practicable types of lead shielding.

In the sixty years since the first sheet lead was rolled for X-ray installations, National Lead has been building up a back-log of experience in fabricating lead shielding.

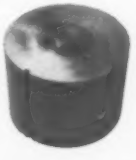
Today, this know-how is being brought into play in the design and manufacture of shields for a growing roster of reactor builders and isotope users and shippers. National Lead plants across the country are called on for run-of-the-mill types of shielding... and are called in for engineering discussions on custom-built shields.

Where the protection of personnel and property is the goal, it makes good sense to find out what the "leader in lead" has to offer in the way of know-how and fabrication facilities.

DEPLETED URANIUM SHIELDING

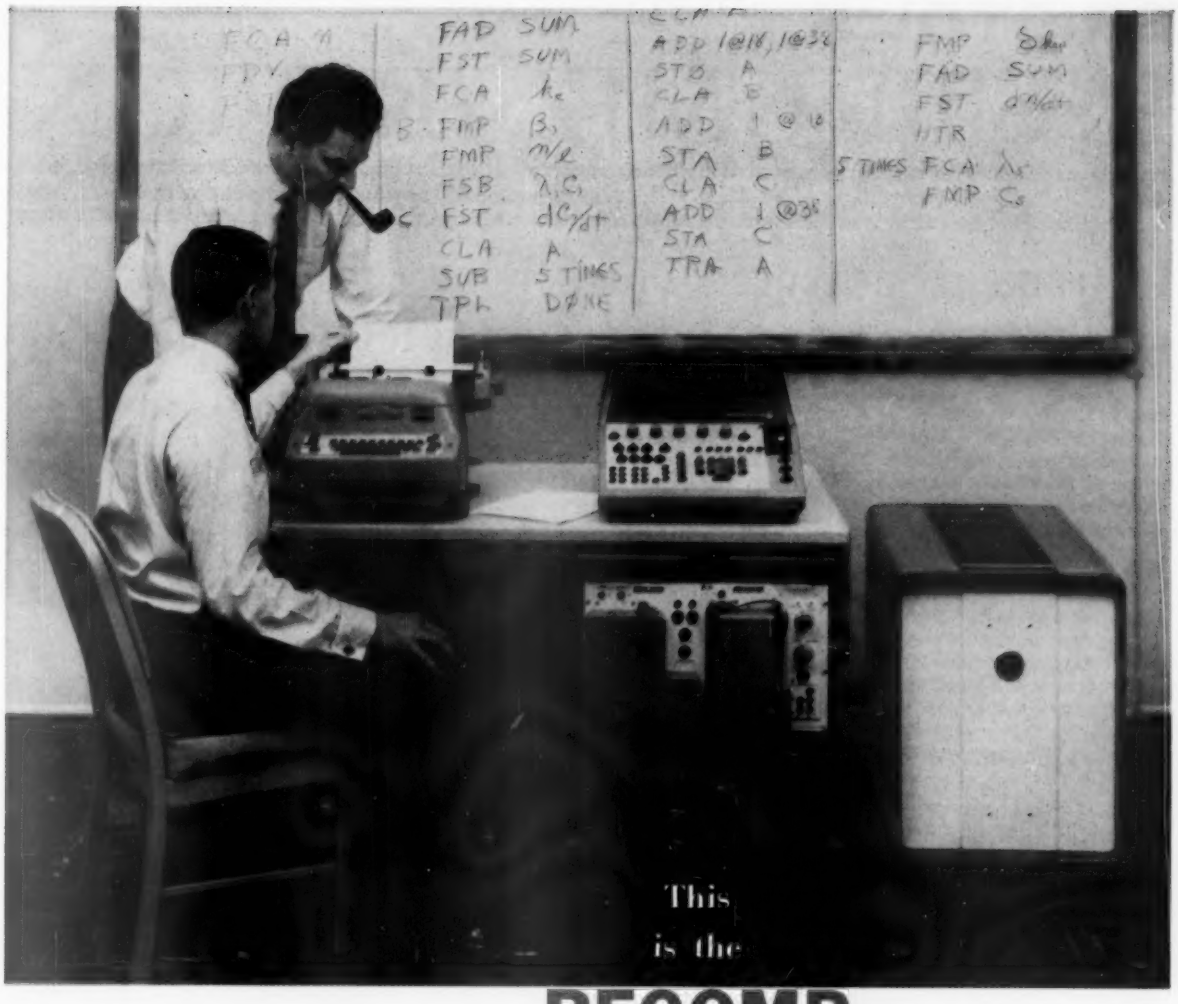
This shield plug for a sample removal cask for the MTR was made by Nuclear Metals Division of National Lead. The machined depleted uranium casting (left) weighed approx. 900 lbs. The finished shield plug (right) fully encased in stainless steel, weighed approx. 1100 lbs.

(Foot rule suggests dimensions.)



National Lead Shielding

NATIONAL LEAD COMPANY · New York 6; Atlanta 9; Baltimore 3; Depew (N. Y.); Chicago 80; Cincinnati 3; Cleveland 13; Dallas 2; Pittsburgh 12; St. Louis 1; Boston 6 (National Lead Co. of Mass.); Los Angeles 23 (Morris P. Kirk & Son, Inc.); Toronto, Canada (Canada Metal Company, Limited)



RECOMP

digital computer

It has a storage capacity of 8,000 instructions . . . and it's low-priced

No problem is too complex to tackle with Recomp—and you can afford to put it wherever it's needed to break up computer-time bottlenecks. It's easy to use, too; engineers quickly learn to program their own problems. *Other Recomp features:* a command structure of 49 arithmetical and logical commands—including 9 built-in floating point commands . . . standardized teletype tape configuration . . . all-transistorized . . . 400-character-a-second input . . . electronic console that puts all basic controls within fingertip reach . . . simplified coding. Recomp gives you far more capacity, versatility, and trouble-free service for your money. It's available for sale or lease. *There's no extra equipment to buy . . . no cost of installation.* Please write for complete literature. Industrial Products Division, Autonetics, Dept. 29, 3584 Wilshire Boulevard, Los Angeles 5, California.

This engineer learned to program Recomp in two days

Digital computers by Autonetics

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Other offices: Dayton, Ohio; Washington, D. C.

BRISTOL'S INSTRUMENTATION

★ *News and information about automatic controlling,*

Instrument measures, controls any process variable that can be transduced to an electrical quantity

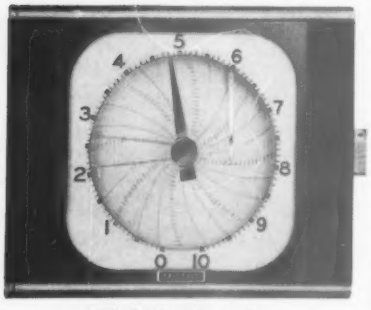
Bristol Electronic Dynamaster* potentiometer and bridge instruments embody design features for utmost accuracy. Many models, many accessories made for extreme versatility

"Over design" insures reliability

The Dynamaster's simple design with few moving parts, plus "over design" in all components insures long life. Easy to use and service, the instrument requires little or no maintenance. Rugged construction . . . ideal for industrial plants, and pilot plants . . . gives the Dynamaster exceptional vibration resistant qualities.

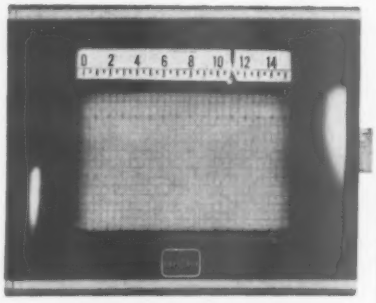
High instrument accuracy

Conservatively rated components, Bristol's careful design and manufacture, combined with the proved Dynamaster motor-driven null-balance principle insure high instrument accuracy and precision in fast electronic measurement and control. Used in miniature as well as full-sized Dynamasters, the motor-driven null-balance design not only provides high accuracy, but also affords plenty of torque for operating alarm contacts, analog to digital converters and other control devices.



Eliminates dry cells

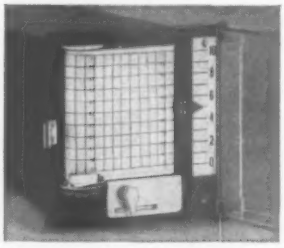
"No-Batt" continuous standardization, available as an optional feature, accurately and automatically standardizes the potentiometer against standard cell continuously, without interruption to service. Dry cells and the usual standardizing mechanism are eliminated. *T.M. Reg. U.S. Pat. Off.



Wide range of models

Dynamaster round chart instruments are available in one- or two-pen models. Strip chart models are available as single-pen, two-pen or multiple-record instruments up to 24 points. Dynamaster models for research and testing include: High speed (0.4 sec) Recorders; Two-Pen Recorders; X-Y Recorders (function plotters); Extended Range Recorders; Adjustable Span and Zero Recorders.

Electronic Dynamaster Pneumatic Transmitter



The Dynamaster is now available as a recording or indicating pneumatic transmitter. This new miniature instrument is offered as a potentiometer, pyrometer, d-c bridge, or a-c bridge for making such measurements as resistance, conductivity, strain, and many others, or it can be a differential-transformer receiver. It continuously transmits a 3-15 psig air pressure signal which can be used to operate recording and controlling pneumatic instruments, such as Bristol Metagraphic Instruments. Full size Dynamaster air control instruments are, of course, also available.

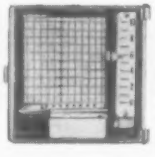
Many electric and pneumatic controllers

Dynamaster round- and strip-chart instruments are available with a wide variety of controllers, both electric and pneumatic.

Electric controllers include on-off, proportional input, 3-position, proportioning, proportional with automatic reset and time program models.

Pneumatic control models include on-off, proportional, proportional with reset and proportional with reset and derivative types in addition to the Dynamaster Pneumatic Transmitter described above.

Dynamaster recorders can be equipped with analog to digital encoders or converters of various types for readout or computer use. This feature extends the already wide range of applications for which Dynamaster instruments are suited.



"Plug-in" miniatures

Bristol miniature Dynamasters (Series 663) take only 5" x 5⅛" panel space. A true plug-in chassis permits 10-second changeover from an indicator to recorder, lets you plug in spare instruments with minimum interruption to control. Miniatures utilize the same highly accurate, motor-driven null-balance principle as full sized Dynamasters which assures ample torque for operating auxiliary equipment or contacts—another advantage over ordinary galvanometer type instruments.

Dynamaster records stomach acidity

Here's a novel Dynamaster application in medical research. Dr. Joseph Gambescia, at Hahnemann Medical College and Hospital, uses a Bristol Recording Potentiometer to study effects of various alkalinizing agents on stomach acidity. The transducer that feeds the Dynamaster is a specially developed glass electrode which is swallowed by the subject.

NEWS AND NOTES

recording and telemetering instruments from Bristol

The now-famous Shippingport, Pa., Atomic Power Station is the United States' first full-scale central station nuclear power plant devoted exclusively to civilian use. Westinghouse Electric Corporation designed and developed the nuclear portion of Shippingport under the direction of and in technical cooperation with the Naval Reactors Branch, U. S. Atomic Enerrgy Commission.

The Bristol Company is one of the intrument suppliers furnishing electronic potentiometer and bridge instruments used here.

Complete temperature profiles increase yield at LCA

Control of time-temperature relationships in decrepitation of lithium ore is critical. Too high temperatures in the huge 250' rotating kiln at the Lithium Corporation of America, Bessemer City, N. C., plant could cause clinker rings and reduce yield. If temperatures are too low the desired chemical conversion will not take place. The problem was how to continually measure internal temperatures throughout the entire length of the kiln. Bristol instrumentation was the answer.

Instruments provide complete temperature profiles within the initial kiln and monitor every step of the process to the final continuous crystallizer. Operators above spot checks temperatures at Bristol panel board. B-47

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Testing the Titan

A panel of Bristol electronic instruments at Martin-Denver Division's Propulsion Laboratory above aids propulsion tests of the Titan ICBM, largest of the Air Force missiles. These Dynamaster recorders were installed as part of the test equipment supplied by Pomona Division, Marquardt Aircraft Co., formerly Associated Missile Products Co. They are used to check out kill parameters during tests. Monitoring engineers can stop tests if the red line limits on critical readings are exceeded.

Record wind tunnel data

Fourteen strip chart Dynamaster millivoltmeters record aerodynamic data from variable resistance strain gages on models under test in the Boeing supersonic wind tunnel. Each recorder is equipped with analog-to-digital converters which convert the Dynamaster potentiometer shaft rotation to digital output. The complete hookup makes possible immediate presentation of computed data simultaneously with the running of the test.

New Dynamaster fits standard 19″ relay rack

Many Dynamaster models now fit into standard 19″ relay racks without modification to rack or instrument. These are the first such instruments that may be so installed without cutting or masking. For more facts, write: The Bristol Company, 147 Bristol Road, Waterbury 20, Conn.

8 PROVEN INSTRUMENTS

to measure and control micro-currents

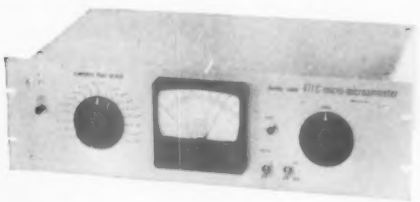
linear micro-microammeters

MODEL 410 offers maximum sensitivity and fast response for general applications. Typical are measurement of currents in ion chambers, photo cells, vacuum tube grids, and back currents of silicon transistors. No switching transients created by switching from range to range. Features tabulated below, with similar Model 411.

log n and period amplifiers

MODEL 420 provides superb stability for dual monitoring of power level and reactor period. It measures positive or negative reactor period from —30 to ∞ to + three seconds and has five-second recovery from overloads. Accuracy is within 3% at center scale. Log N current ranges shown below.

contact-meter micro-microammeters



MODEL 411-C has a meter-relay with adjustable contacts, providing economical control or alarm circuitry. Five-ampere contacts are brought out through an AN connector. All other Keithley Micro-microammeters and Log N Amplifiers also are available with contact meters for specific applications.

logarithmic micro-microammeters

MODEL 412 features a large single scale covering six decades with no range switching. Typical uses include reactor control, radiation monitoring and materials testing. Accuracy is within 0.2 decade; zero drift within 0.5 decade in eight hours. Features shown below, including similar Model 413.

MODEL	FULL SCALE RANGES	OUTSTANDING FEATURES	PRICE
410	10^{-3} to 3 x 10^{-13} amp.	Twenty ranges; fast response; maximum sensitivity	$ 490.00
410-C	10^{-3} to 3 x 10^{-13} amp.	Same as 410 except contact meter replaces panel meter	$ 625.00
411	10^{-3} to 10^{-11} amp.	Seventeen ranges; fast response; excellent zero stability	$ 535.00
411-C	10^{-3} to 10^{-11} amp.	Same as 411 except contact meter replaces panel meter	$ 670.00
412	10^{-13} to 10^{-7} amp.	Single range; high stability log N meter; fast response	$ 485.00
413	10^{-11} to 10^{-5} amp.	Same as 412 except measures larger currents	$ 485.00
420	10^{-13} to 10^{-6} amp.	Single range; adjustable response speed; superb stability	$ 950.00
420-C	—30 to ∞ to + 3 sec.	Same as 420 except two contact meters replace panel meters	$1220.00

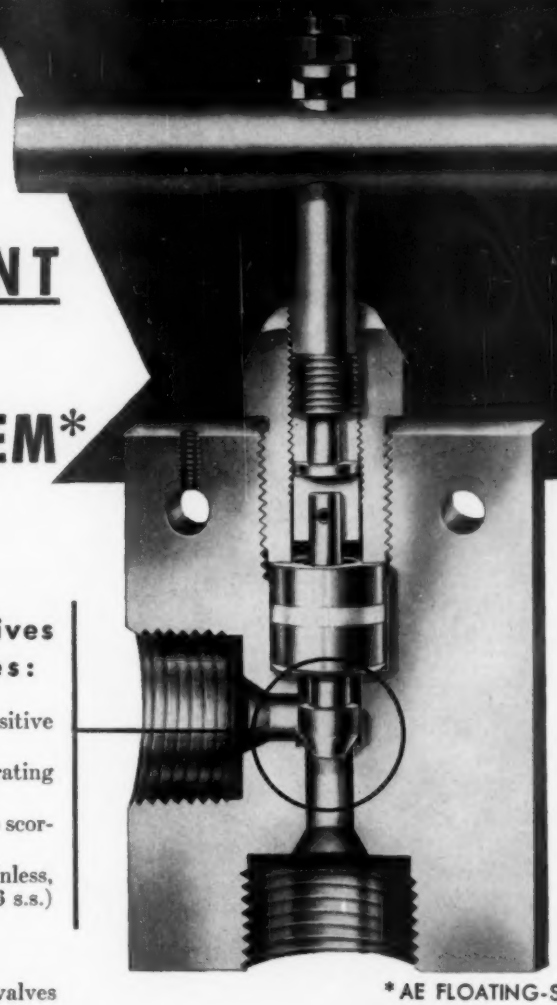
WRITE TODAY *for detailed data on these and other Keithley Instruments for nuclear and research applications.*

KEITHLEY INSTRUMENTS, INC.

12415 EUCLID AVENUE CLEVELAND 6, OHIO

NEW From AUTOCLAVE ENGINEERS

A MAJOR IMPROVEMENT IN FLOATING-STEM* VALVES



Only This Unique Design Gives You All These Advantages:

- **No "Backlash"** — Stem movement is positive at all times
- **Pre-Loading Construction** — assures operating without "slop"
- **Stem Does Not Rotate Against Seat** — No scoring of either stem or seat
- **Choice Of Lower Stem Materials** — Stainless, hastelloy, monel, etc. (standard stem 316 s.s.)

This major improvement in floating-stem valves gives you operating advantages available in no other valve. When you operate this valve, you get positive stem action immediately . . . no "backlash", no "play", no loss of "feel", and no scoring because the floating stem does not rotate against the seat. You have a choice of lower stem materials such as stainless steel, hastelloy, titanium, monel, etc.

And these new floating-stem valves give you the same finger-tip control, the same leak-proof action characteristic of *all* AE Valves. What's more, you can install the new floating-stem in your present AE Valves—easily, quickly. Whenever corrosion or scoring is a problem, *always* specify AE Floating-Stem Valves.

*AE FLOATING-STEM VALVES are patented Pat. No. 2,887,293

For More Details On
AE FLOATING- STEM VALVES,
Send For Bulletin 5152-A

AUTOCLAVE ENGINEERS, INC

2935 WEST 22nd STREET, ERIE, PENNSYLVANIA

LOW RANGE POCKET CHAMBERS AND MODEL L-60 CHARGER-READER

Model L-65 chamber is used in very large numbers in atomic production plants in the United States. It is also a standard model for laboratories, clinics, etc. It provides much lower cost than other methods over a period of two years or more and is much more accurate. Its energy dependence is less than 10% from Co-60 to 50 kev.

Model L-69 is the counterpart of Model L-65. It is equally sensitive to thermal neutrons as to X and gamma rays.

Models L-70 and L-81 are "midget" size chambers. In Model L-70 the gamma and X-ray sensitivity has been suppressed so the reading is 200 mrem full scale for thermal neutrons only. Model L-81 is an X and gamma ray chamber of 2 r full scale range. It is normally worn with an open adjustable finger ring to protect the hands of isotope workers.

All these chambers are charged and read on Charger-Reader Model L-60. Their accuracy is ±5% of true dose at midscale. Linearity of scale is within ±3%.

Model L-60 is a well-designed and thoroughly seasoned unit. It uses the rugged type quartz fiber voltmeter which is used in dosimeters. Batteries are easily replaced. They consist of one 1½ volt size D cell to provide light for the microscope field and six 22½ Volt No. 412 Minimax batteries. Their life is at least two years (shelf-life). The scale is marked 0 to 200 so that all the above mentioned meters can be read without interpolation.

MODEL NO.	RANGE	TYPE OF RADIATION	DIAMETER	LENGTH
L-65	200 mr	X-rays, gamma rays	1.26 cm	8.90 cm
L-69	200 mrem	X, gamma, thermal neutrons	1.26 cm	10.6 cm
L-70	200 mrem	Thermal neutrons only	1.26 cm	4.5 cm
L-81	2 r	X-rays, gamma rays	1.26 cm	4.5 cm

Landsverk Electrometer Company

641 SONORA AVE., GLENDALE 1, CALIFORNIA

Now available in commercial quantities:

Spencer Stoichiometric Fused and Ground UO_2 For Swaged Fuel Rods

A unique process has been perfected by Spencer Chemical Company for the fusing and grinding of stoichiometric uranium dioxide that results in individual particles approaching theoretical density. Here are the properties of this material:

1. **Compaction densities:** as high as 93% in either stainless steel or zircaloy tubing. Initial results with aluminum tubing indicate as high as 89% density.

2. **Uranium dioxide composition:** $UO_{2.005}$.

3. **Particle size:** normally offered in −20 mesh particle size. Special orders may be made in any particle size distribution desired.

4. **Tap densities:** Example A, −20 mesh—7.0 to 7.3 gm/cc; Example B, −20 mesh/+100 mesh—6.5 gm/cc.

5. **Moisture:** Typical analysis: less than 0.1%.

6. **Enrichments available:** (1) depleted from uranium hexafluoride or process scrap; (2) normal from mill concentrate ("yellow cake") or process scrap; and (3) all levels of enriched from uranium hexafluoride or process scrap.

7. **Typical spectrographic analysis** (−20 mesh material):

Element	ppm	Element	ppm
Silver	0.3	Manganese	20
Aluminum	25	Molybdenum	2
Boron	0.5	Nickel	10
Cadmium	0.1	Phosphorus	10
Chromium	10	Lead	5
Copper	5	Silicon	120
Iron	150	Tin	1
Magnesium	30		

8. **Availability:** laboratory quantities or production quantities.

Also available from Spencer Chemical Company is ceramic grade uranium dioxide that will sinter to a fired density of 10.5 grams per cc. This material is made by Spencer's unique continuous process.

For complete details, contact Spencer Chemical Company, Nuclear Fuels Department, Dwight Building, Kansas City 5, Missouri.

SPENCER URANIUM DIOXIDE

A Product Of

SPENCER®

Spencer Chemical Company

America's Growing Name In Chemicals

General Offices: Dwight Building, Kansas City 5, Missouri

Navy goes fission again

On this vertical boring mill at U. S. Steel's Homestead Plant, you see a forged steel flange that will serve aboard one of the Navy's new guided missile frigates. These are an entirely new class of naval vessel—their primary mission is the destruction of air targets and they are nuclear-powered.

The flange will be welded to other forged steel parts to form a sealed nuclear reactor vessel. Only a forging of the very best quality is suitable for this critical service. To obtain this quality, vacuum-cast electric furnace steel was used. The flange was carefully forged from a Ni-Cr-Mo alloy ingot about 72" in diameter and was heat treated to meet rigid specification requirements. Mechanical tests as well as magnetic particle and sonic inspection methods were utilized to assure a quality product. As shipped, the flange weighed over 21½ tons.

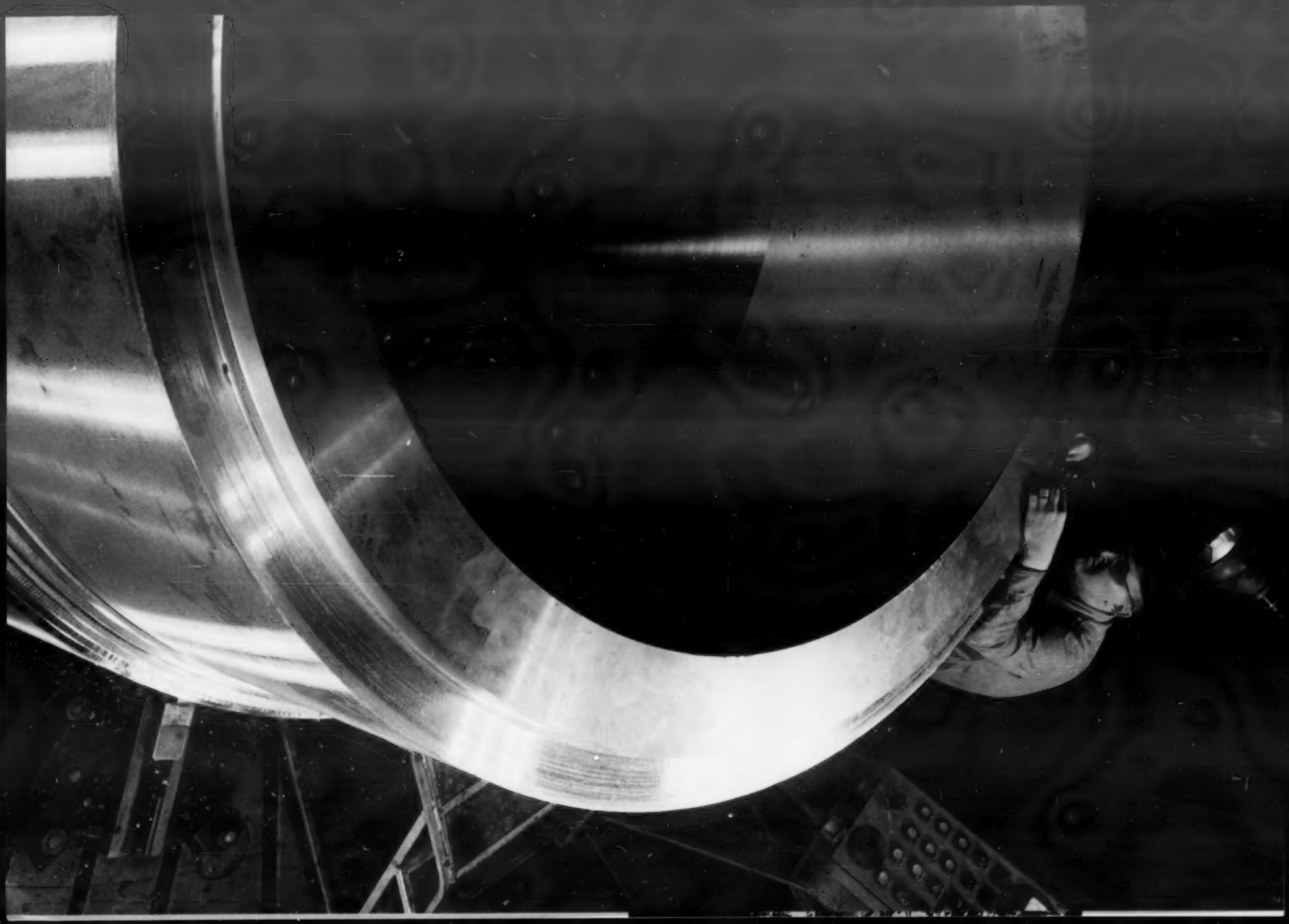
Many nuclear forgings like this one are made by U. S. Steel because here, the complete production is supervised and controlled by a team of forging experts. They melt the steel, pour the ingot, forge, heat treat and machine it. The very same team of USS Forging experts who made this flange will fill your order. We welcome your inquiries or requests for our free 8-page booklet about USS Nuclear Forgings. Write to United States Steel, 525 William Penn Place, Room 6032, Pittsburgh 30, Pa.

USS is a registered trademark

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Export Company

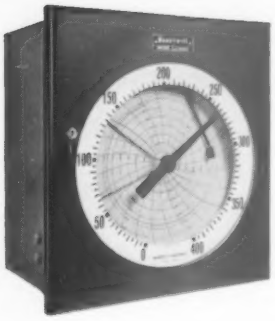
United States Steel

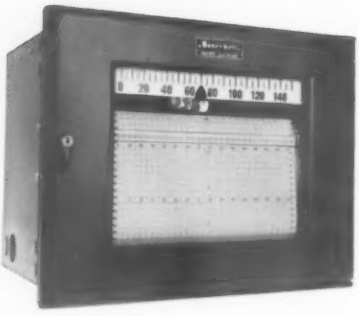
USS



New Constant Voltage Unit makes *ElectroniK* instruments better than ever

by eliminating these problems





All new Precision Line *ElectroniK* circular and strip chart instruments have the new Honeywell Constant Voltage Unit that accurately regulates d-c reference supply to the measuring circuit. No more batteries, standard cells or standardizing mechanisms . . . and no more of the problems they pose.

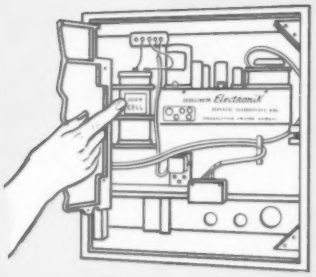
The Constant Voltage Unit delivers a constant, rectified voltage from line supply. It uses dependable Zener diodes and a reliable ambient temperature compensator.

This latest improvement in *ElectroniK* instruments assures even greater dependability, and less maintenance, and is still another reason why *ElectroniK* instruments are your best value in measurement and control. Get full details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

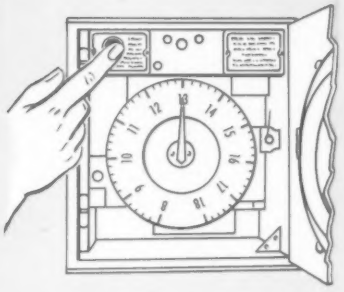
MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

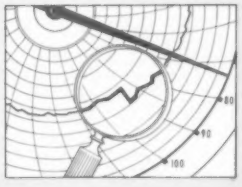
First in Control



No batteries **to replace . . . no recording or control deviation due to low battery voltage.**

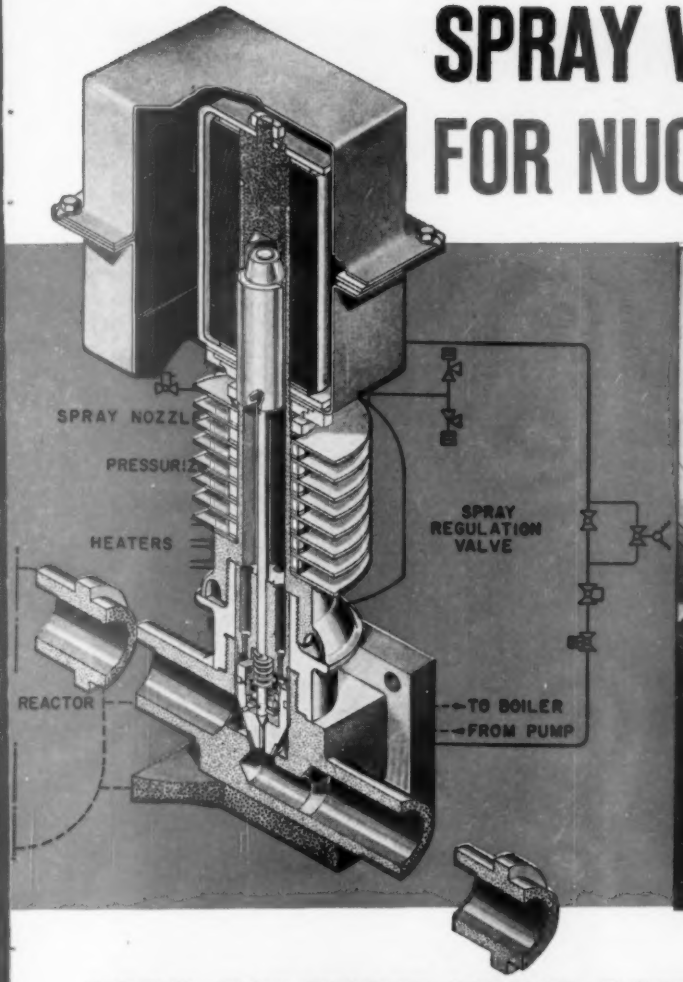


No button **to push on the instrument for standardization . . . no false readings because of failure to standardize.**



No blanks or shifts **in the instrument's response to variables. You get complete continuity of recording and control.**

SPRAY VALVE FOR NUCLEAR REACTORS...



ASCO SOLENOID VALVE CONTROLS PRESSURE SURGES

ASCO – the only solenoid valve manufacturer in the industry with complete nuclear energy test facilities including a *hot test* loop – now offers a family of solenoid valves designed specifically for atomic energy applications.

The Spray-Valve shown in the cutaway above was developed especially to control pressure surges in the water cooled pressurized reactor. All stainless steel with stellite seats and discs, this unit has demonstrated reliability and maintenance-free operation under tests which duplicated the most strenuous operating conditions.

This packless type (hermetically sealed) solenoid valve is capable of large volume flow at low pressure differentials, handles pressures of 2500 p.s.i., at 675°F. Normally closed (closed when de-energized), it is supplied in 1", 1½" and 2" sizes.

ASCO Spray Valves are in use at Shippingport Atomic Power Station, and aboard nuclear submarines powered with water cooled reactors. Reliable and maintenance-free, ASCO 2, 3 and 4-way valves are specified for primary and secondary systems of nuclear reactors, as well as for instrumentation control.

For further information, request "ASCO Valves for Nuclear Reactors" and Catalog No. 202.

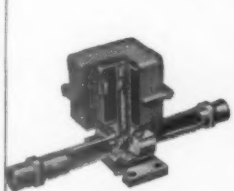
ASCO®

Automatic Switch Co.

52-M Hanover Road, Florham Park
New Jersey.
FRontier 7-4600.

Typical ASCO Solenoid Valves for submarines, military and commercial surface ships, and industrial power plants:

Primary System

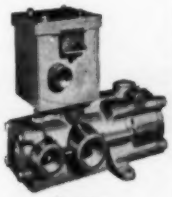


Isolating (Stop) Valve

Pressure Operated 4-way Valve

Secondary System

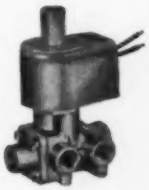
Manual Reset 2-way Valves



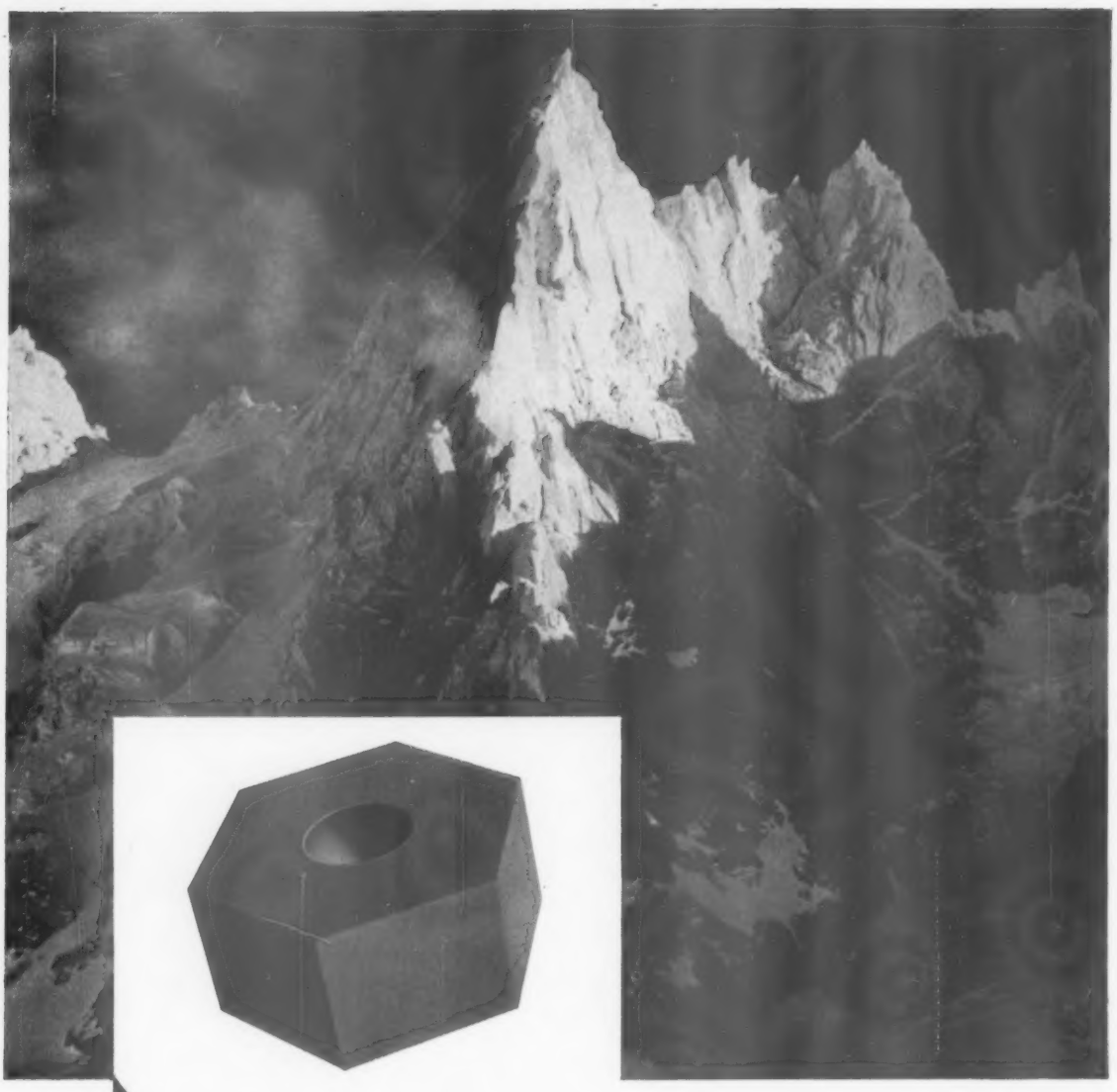
4-way Valves

Instrumentation Control

Manual Reset Valves



4-way Valves



Beryllium oxide

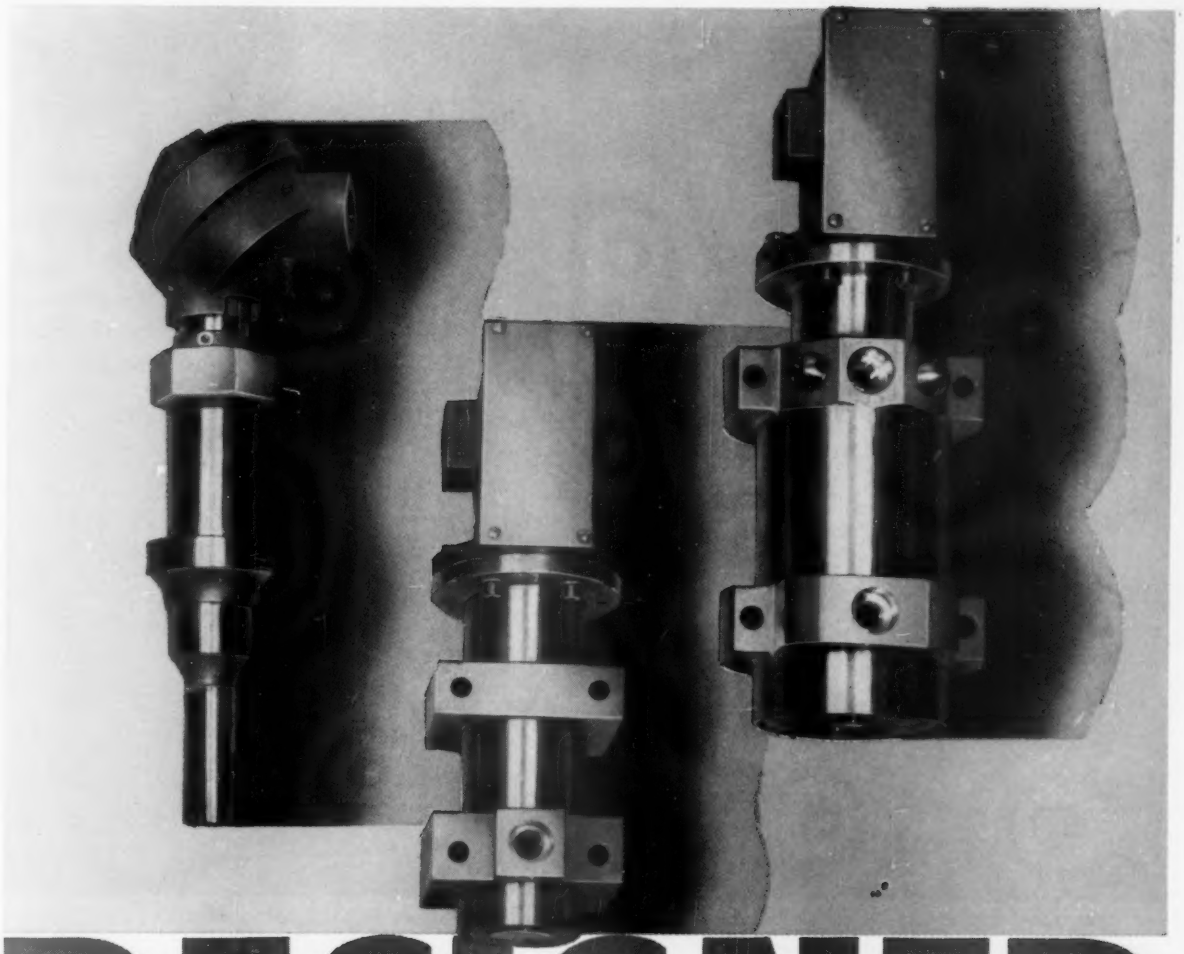
Nuclear grade oxide
(boron 0,3 ppm - rare earth 0,005 ppm)

Hydroxide and oxide powders

Sintered products
(specific weight up to 2,95 g/cc)

PECHINEY Division Applications Atomiques

23 RUE BALZAC PARIS 8e



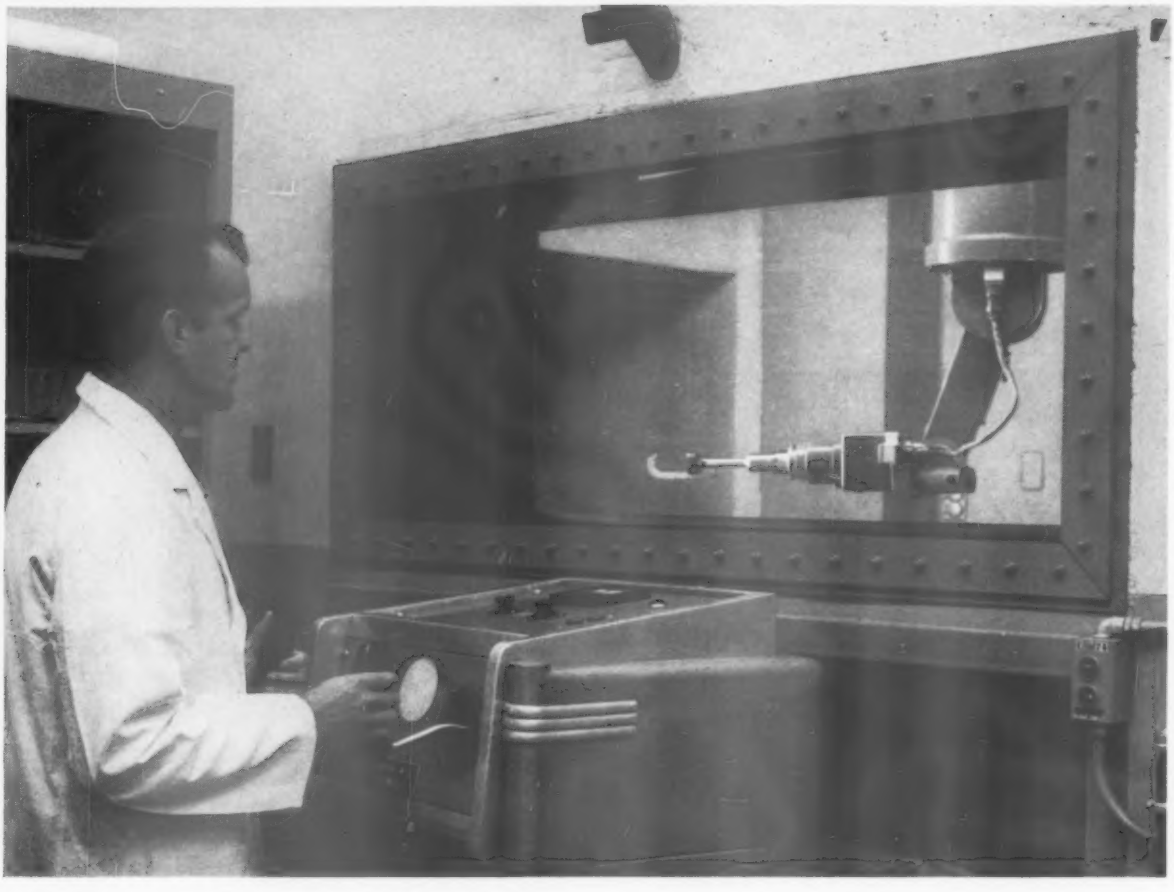
DESIGNED

SPECIFICALLY FOR NUCLEAR APPLICATIONS

These transducers are an engineered family of highly reliable instruments for measuring pressure temperature, flow, liquid level and differential pressure. » » Compact and rugged construction enables the units to meet the severe environmental conditions of MIL-N-19900 while maintaining outstanding accuracy. » » For any transducing application wherein reliability is a paramount consideration you should review the specification of these nuclear transducers. ***Consolidated Controls Corp.*** also designs and manufactures complete Instrumentation and Control Systems using static components. Complete details available by contacting Dept. NT.

CCC ***CONSOLIDATED CONTROLS CORP.***

BETHEL, CONN., INGLEWOOD, CALIF.
A SUBSIDIARY OF CONSOLIDATED DIESEL ELECTRIC CORPORATION,
STAMFORD, CONNECTICUT



General Mills "Muscle-Man" with a Gentle Touch

At the Naval Research Laboratory, this General Mills Mechanical Arm helps solve nuclear handling problems

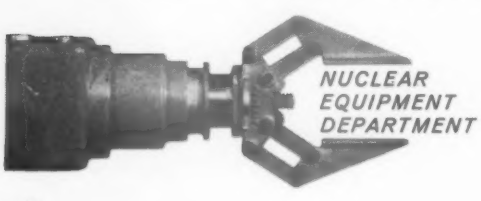
At the Naval Research Laboratory—as in almost every other major atomic installation in America—the General Mills Mechanical Arm solves remote handling problems. It lifts great weights with ease, yet handles fragile material safely. Each of the three models of Mechanical Arm is adaptable to nearly any installation requirement.

Facilities planning and a full line of remotely controlled handling devices: heavy duty and underwater manipulators; power tools and accessories; crane hoists; boom or wall mounted manipulators; mobile remote handlers; fuel handlers; reactor service and maintenance equipment; these and many more are included among the standard or custom design products and services offered by the Nuclear Equipment Department of the Mechanical Division.

If your operation involves remote handling, you'll want to contact the Nuclear Equipment Department of General Mills. If we have not already built remote handling devices which will satisfy your requirements, we have the experience and know-how to design custom equipment to suit your needs.

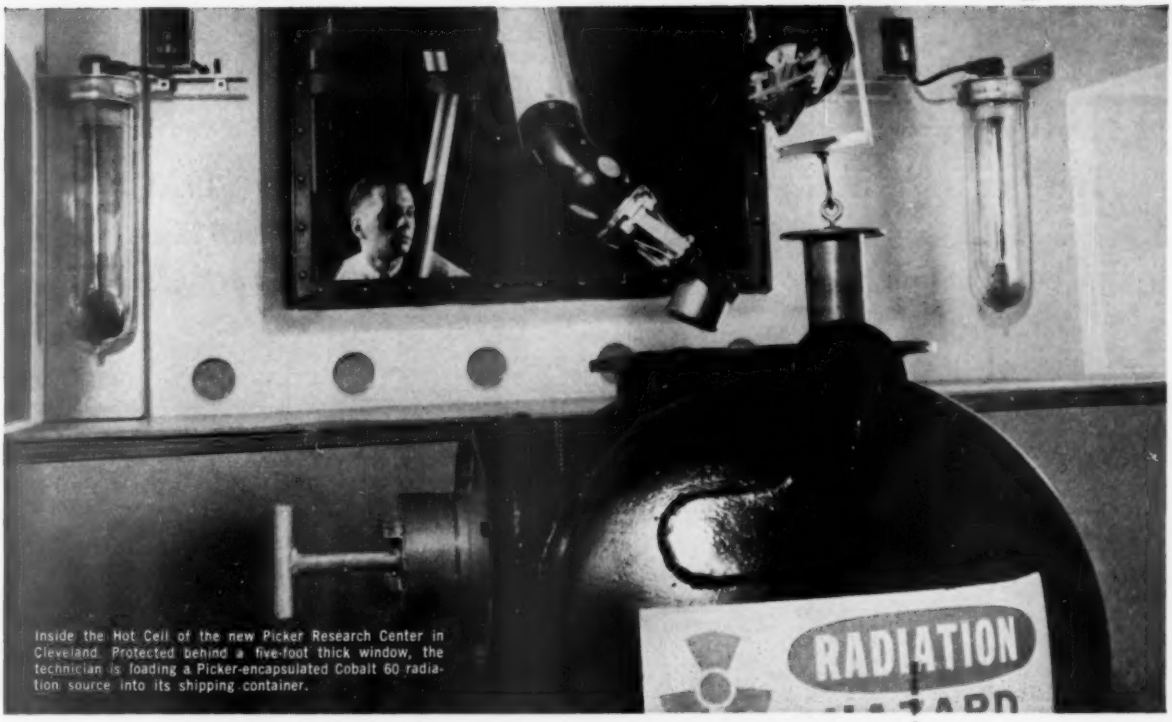
Write for our five new engineering bulletins:

Nuclear Equipment Department
Mechanical Division of General Mills
419 North 5th Street
Minneapolis 1, Minnesota



First In Remote Handling
MECHANICAL DIVISION
Minneapolis, Minnesota

General Mills



Inside the Hot Cell of the new Picker Research Center in Cleveland. Protected behind a five-foot thick window, the technician is loading a Picker-encapsulated Cobalt 60 radiation source into its shipping container.

What's YOUR interest in radiation?

want to **try** it? — to find out what it can do for you? (improve product quality, reduce cost, things like that)

want to **use** it? — for industrial or medical radiography or therapy? for research?

want to **produce** it? — for bulk sterilization, product-irradiation?

want to **measure** it? — to be sure there's no hazard? to know the dose rate?

want to **shield** it? — for personnel and public protection?

want to **diffract** it? — for structure studies or fluorescent analysis?

WHATEVER your concern, we can probably help you

we've the **background** for it — as leading producers of x-ray and isotope radiation equipment, we've been *living* with radiation for over 40 years

we've the **facilities** for it — a Research Center with a million-curie hot cell, gamma garden, hot laboratories

we've the **will** for it — a Sales/Service network with local offices in principal cities of the U.S. and Canada

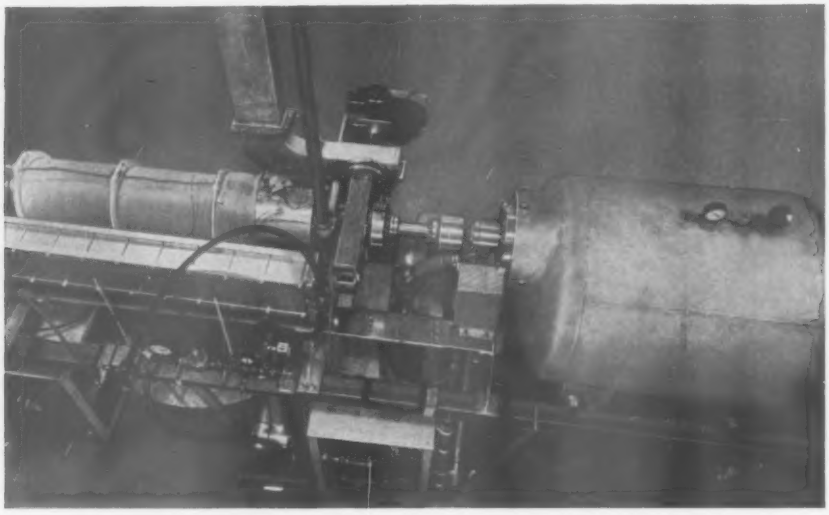
Contact any Picker office (see local 'phone book) or write, wire, phone Picker X-Ray Corporation, 25 South Broadway White Plains, N. Y., WHite Plains 8-0080

if it has to do with RADIATION it has to do with Picker x-ray

arco APPLIED RADIATION news

The first of a new generation of high power linear accelerators

High beam power at 10 Mev and beyond from ARCO L-band Linac



The ARCO L-band accelerator may be seen in actual operation at ARCO's Walnut Creek, California plant. Come and see it perform.

A new theoretical concept, developed by ARCO physicists, now proved beyond question.

First use of the lower L-band frequencies; higher power at lower cost.

A sweeping redesign of accelerating waveguide structures, radical with respect to conventional approaches.

Dependable Litton Industries L-band klystrons and other high-reliability production model components.

Accumulated experience of the world's largest designer-builder of electron linear accelerators.

Above are the basic ingredients which produced the new high energy, high power ARCO L-band linac—available now for unique experimentation or investigation, or practical, low cost per kw-hr radiation processing.

Data produced during exhaustive theoretical design and experimental testing on the first ARCO L-band machines are so conclusive that construction contracts in excess of $3,000,000 have been awarded for ARCO L-band accelerators.

A major advantage of the new machine is that it is not subject to the limitations (such as pulse shortening) in peak and average beam power levels that have plagued performance of earlier machines. Pulse shortening above the 4 kw level has been eliminated, despite output many times that of previous linacs. Performance of the new L-band machine shows that high power can be obtained even at energies up to 80 Mev.

Purchasers and engineers who have inspected the new ARCO machine believe it will usher in a completely new era in research and processing.

In research, the ARCO L-band machine makes possible exotic physics experiments such as neutron time-of-flight studies using flight paths up to ¼ mile in length. It greatly extends the range of experiments possible in single pulse radiation effects studies. It also permits measurement of transient effects in neutron multiplying assemblies.

In industrial processing, the higher performance and corresponding reduction in cost per kw-hr. are expected to make practical many applications which have looked promising in the laboratory but have been ruled out by high operating costs. Examples are polymerization processes, reforming of petroleum fractions, modification of polymers as in cross-linking, grafting and vulcanizing and commercial production of isotopes.

Data on the new ARCO L-band accelerator awaits your letter. Specific proposals appropriate to your application can be provided quickly and comprehensively. Your inquiry is invited.

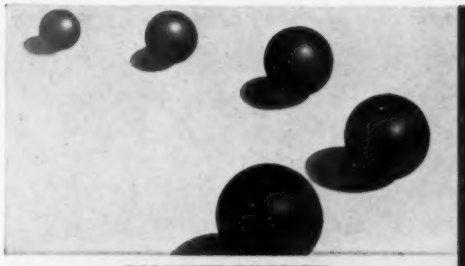
ARCO APPLIED RADIATION CORPORATION

World's largest manufacturer of linear electron accelerators

Walnut Creek, California • YEllowstone 5-2250 • Cable "ARCO"

Department 9-N

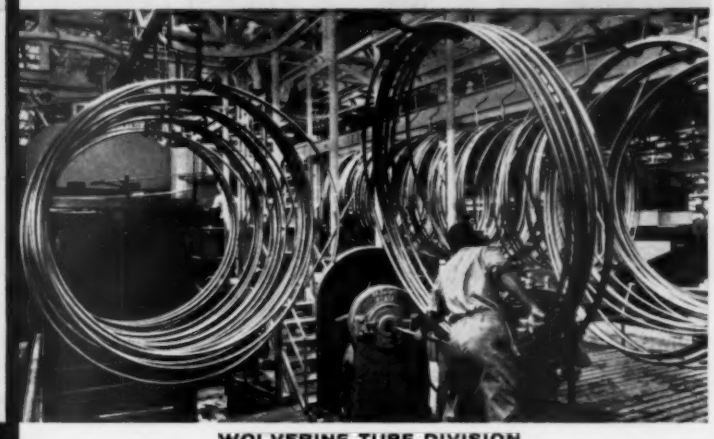
6051



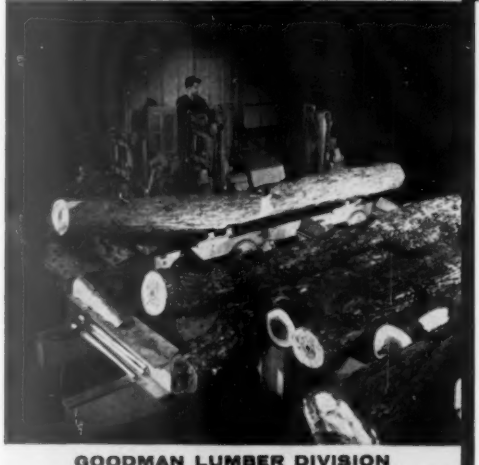
CALUMET DIVISION

LOOK TO WOLVERINE TUBE

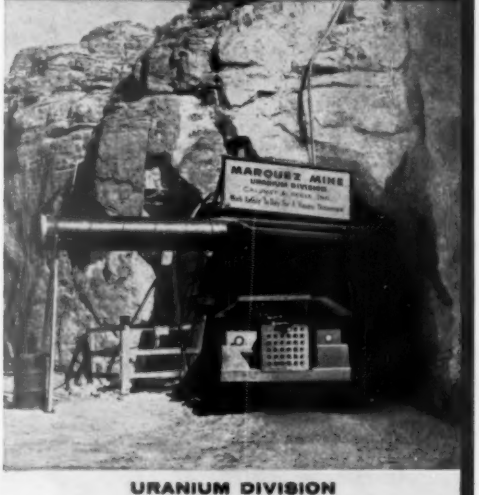
LOOK TO CALUMET & HECLA...



WOLVERINE TUBE DIVISION



GOODMAN LUMBER DIVISION



URANIUM DIVISION

Mining . . . refining . . . lumbering . . . agriculture . . . manufacturing — diversified indeed are the product and market areas of the companies making up the industrial family of Calumet & Hecla, Inc.

Of course, Calumet & Hecla has for many years been recognized as a copper producer. Since 1859, in Michigan's Upper Peninsula, the Calumet Division has been mining Lake copper — one of the purest forms of copper ore. The refined product is sent to Wolverine Tube Division for conversion into brass and copper tubing for plumbing installations, refrigeration, chemical and petroleum processing as well as for a wide variety of general industrial applications. Wolverine Tube is also a prime manufacturer of aluminum extrusions, and drawn and extruded aluminum tube.

The Calumet Division is widely recognized for the quality of the grinding balls and mill liners it manufactures for the mining industry, as well as for the agricultural oxides it produces for better farming.

From the trees in the vast forest areas of Calumet & Hecla holdings, Goodman Lumber Division manufactures plywood and other wooden products. C&H properties have turned up high grade uranium. The development of these properties and the extraction of this valuable element is the responsibility of the Uranium Division.

If any of the above products fall within the scope of your company's requirements, remember that you pick a winner every time you deal with a member of the Calumet & Hecla industrial family.

When you need tubing—LOOK TO WOLVERINE!!

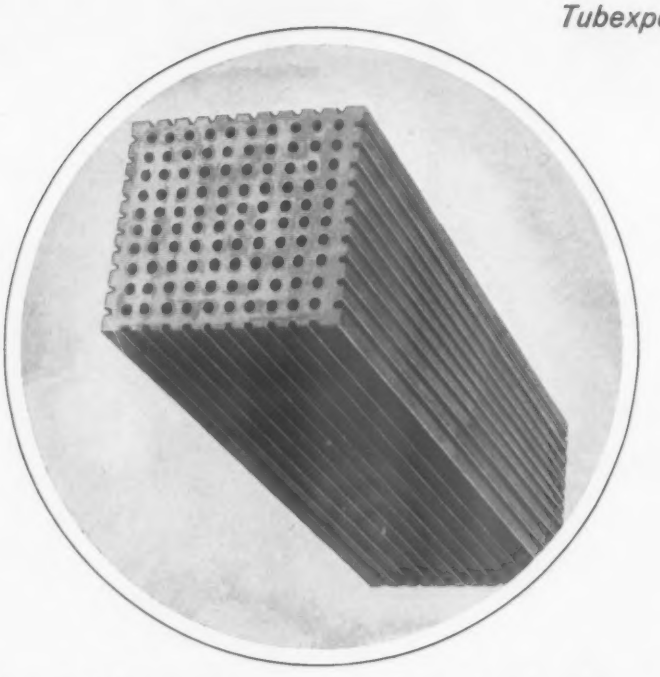
CALUMET & HECLA, INC.
CALUMET DIVISION
URANIUM DIVISION
GOODMAN LUMBER DIVISION
WOLVERINE TUBE DIVISION

In Canada:
CALUMET & HECLA OF CANADA LIMITED
WOLVERINE TUBE DIVISION
CANADA VULCANIZER & EQUIPMENT CO. LTD.
UNIFIN TUBE DIVISION

WOLVERINE TUBE
DIVISION OF
CALUMET & HECLA, INC.
17260 Southfield Road
Allen Park, Michigan
Manufacturers of Quality-Controlled Tubing and Extruded Aluminum Shapes

PLANTS IN DETROIT, MICHIGAN AND DECATUR, ALABAMA.
SALES OFFICES IN PRINCIPAL CITIES.
EXPORT DEPT. 13 E. 40TH ST. NEW YORK 16, N.Y.

Tubexperience in action



How to get the tubing you need for fuel element cladding

In selecting tubing for fuel element cladding in nuclear reactors, the following factors must be considered and properly evaluated:

1. Type of fuel—ceramic or metallic matrix

2. Environment—temperature, pressure and corrosive conditions encountered

3. Neutron economy—whether materials like zirconium, columbium, vanadium or Zircaloy, which have the best nuclear characteristics, are to be used; or whether less effective substitutes must suffice as a cost consideration

4. Standard of reliability and integrity—what is wanted, what it is possible to produce, what is economically feasible

5. Dimensional requirements—OD, ID or wall thickness or any combination of these; straightness of tubing; and tolerances to be held

The following composite inquiry will show what Superior does to give its customers the utmost satisfaction:

Analysis: Seamless 304, .002% max. cobalt limitation, chemistry restriction.

Size: .443 in. ±.0005 in. OD × .423 in. +.0005 in. —.0000 in. ID. Cut lengths, tolerances 1/64 in.

Tests: Nondestructive ultrasonic, to a 3% wall defect level; helium leak test; autoclave corrosion test; 2-hr. hydrostatic test.

Other Requirements: Dye penetrant inspection; no chlorinated lubricants or cleaning fluids permitted.

Here is the tubing supplied by Superior and the requirements which it met:

Analysis: 304L because of application temperature. By special melt we got .01% max. cobalt level. By converting ingot we attained a .003% max.

Size: Tolerances of ±.001 in. OD and +.001, —.000 in ID. We air-gaged to insure ID tolerances.

Ultrasonic Test: Agreed upon a defect level of 10% of the wall, since wall thickness was less than .040 in. We also recommended Eddy current.

Helium Leak Test: Customer waived this test. It has been dropped from Nuclear Military Specifications. It is used on completed assemblies only.

Autoclave Corrosion Test: Time and temperature test made.

Hydrostatic Test: It was decided to limit this test to completed pressure vessel.

Dye Penetrant Inspection: Performed according to specifications.

Chlorinated Lubricants or Cleaning Fluids: Since use of them is general procedure in all tube processing plants, customer withdrew restriction.

Identification: This can be met, although costly. Customer waived requirement.

Superior's experience in the nuclear and missile field can help you develop fuel element cladding to satisfy any special requirements. Write for a copy of Data Memorandum No. 20 and more information. Superior Tube Company, 2027 Germantown Avenue, Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

ATOMIC POWER

When this revolutionary power first showed its potential, Crane was ready to develop the special kinds of valves needed to control it. Today on sea and land, wherever atomic power is being proved, Crane valves also are proving their greater dependability. This new industry, like all others, looks first to Crane for valves —for the basic reasons below:

USS Nautilus on her heroic voyage under Arctic ice cap. Painting by Charles P. Wood, Jr.

SERVICE

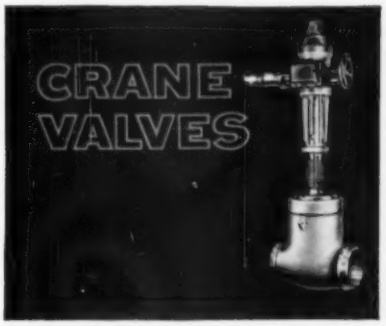
To all industries Crane offers the widest choice of valves and fittings for every need—available from local stocks through Crane branches and wholesalers everywhere.

ECONOMY

Traditionally the pace-setter of quality, and as the industry's largest producer, Crane offers premium quality at economical cost—a double assurance of greater value.

ACCEPTANCE

Crane stands for leadership in valve engineering research and development—another reason why more Crane valves and fittings are used than any other make.



Stainless steel gate valve for main coolant service in pressurized water reactor system—built like a watch.

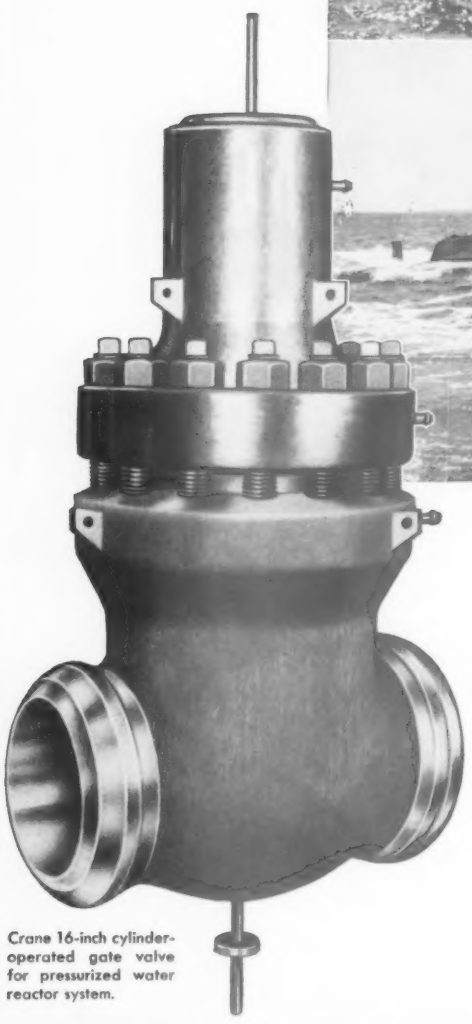
CRANE®

CRANE CO.
General Offices: Chicago 5, Illinois
Branches and Wholesalers in All Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING • AIR CONDITIONING

Ever since nuclear power went to sea Crane valves have provided safe controls

U.S.S. Skipjack
(Below)
U.S.S. Skate
(General Dynamics Corp. photos)



Crane 16-inch cylinder-operated gate valve for pressurized water reactor system.

The daring imagination of naval pioneers who first powered submarines with atomic reactors was matched from the beginning by the resourcefulness, knowledge and skill of Crane engineers and craftsmen.

From their drawing boards, foundries and machines came valves that provided safe flow control of the radioactive materials making nuclear-powered propulsion possible.

Today Crane valves go to sea on reactors and auxiliary service lines on board the *Nautilus* . . . *Seawolf* . . . *Skate* . . . *Sargo* . . . *Skipjack* . . . *Swordfish* . . . *Seadragon* . . . and they will be on many other submarines still to be built.

Crane valves will be aboard nuclear-powered surface ships, too: the cruiser *Longbeach* . . . new destroyers and carriers. And they're on the new passenger-cargo ship *N/S Savannah*.

If your plans for ships or naval power plants call for atomic energy as fuel, consult your Crane Representative now for information about these valves—or write to address below.

CRANE® VALVES & FITTINGS

PIPE • PLUMBING • HEATING • AIR CONDITIONING

Since 1855—Crane Co., General Offices: Chicago 5, Illinois—Branches and Wholesalers Serving All Areas

atomic progress

THROUGH

58 YEARS

pioneer

SERVICE

&

ENGINEERING CO.

231 S. La Salle Street,
Chicago, Illinois

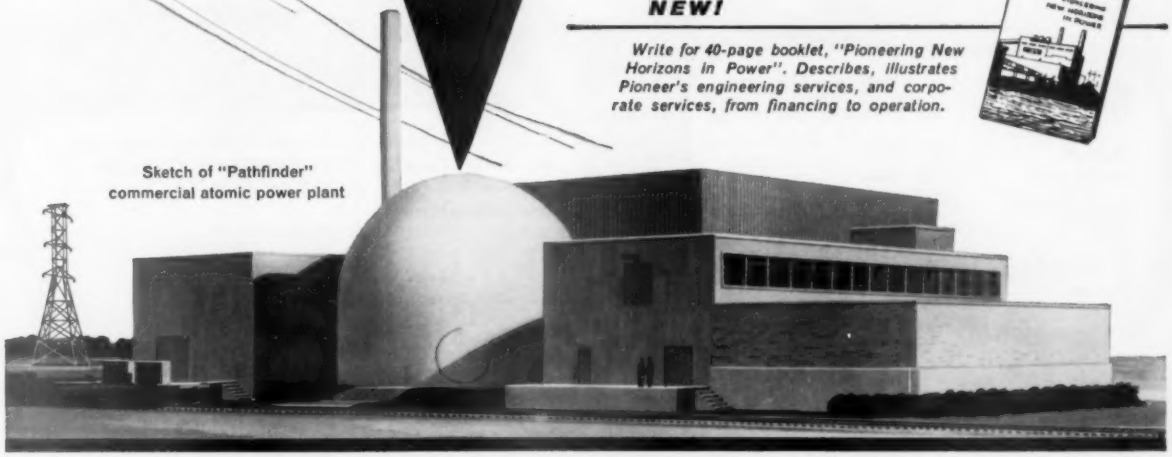
In 1952 Pioneer joined with other groups, all reporting to the Atomic Energy Commission, for constant study of atomic energy application. Today Pioneer is qualified as a consultant to industry in the application of atomic reactor systems to the generation of electric power. Presently, Pioneer is acting as architect-engineer and supervisor of construction of the 66,000 kw commercial atomic power plant shown here. Allis-Chalmers Mfg. Co. is the prime contractor. Scheduled for 1962 completion, the plant, for the Northern States Power Co., will be known as the "Pathfinder".

Organized as Central Utilities Atomic Power Associates, these utilities will share in the research and development costs: Northern States Power Co., Central Electric and Gas Co., Interstate Power Co., Iowa Power and Light Co., Iowa Southern Utilities Co., Madison Gas and Electric Co., Mississippi Valley Public Service Co., Northwestern Public Service Co., Ottertail Power Co., St. Joseph Light and Power Co., Wisconsin Public Service Corp.
PIONEER SERVICE & ENGINEERING CO., 231 South La Salle Street, Chicago, Illinois

NEW!

Write for 40-page booklet, "Pioneering New Horizons in Power". Describes, illustrates Pioneer's engineering services, and corporate services, from financing to operation.

Sketch of "Pathfinder" commercial atomic power plant



rigid specifications

Tension tests are required to be made at room temperatures and at 670° F. The following minimum physical properties shall be met:

At Room Temperature:

TS	YS	EL	RA	CHARPY V-NOTCH
70,000	30,000	45	50	50

At 670° F. the minimum tensile strength shall be 51,000 p.s.i. and the minimum yield strength 18,300 p.s.i.

Rejection

Each casting that develops unacceptable defects during shop working or fails to conform to all of the requirements of these specifications shall be rejected. No repair by welding or other means will be permitted.

Radiographic Inspection

(a) Paragraph S5 (a) of the Supplementary requirements of ASTM-A 362-52T.

(b) All castings shall be radiographed 100% and shall conform to ASTM-E7 1-52, Class 2 quality, except as modified by these specifications.

(c) The manufacturer shall establish a positive system of identification of the X-ray plates which shall be subject to approval by the inspector. This system shall guarantee complete coverage by radiographing and provide for positive identification between the plate and the subject.

Inspection of Penetrants

All castings shall be subjected to inspection by fluorescent penetrants or penetrating dyes both inside and out. All cracks, porosity, or flaws revealed as a result of the Dye Penetrant Test shall be due cause for rejection of the casting.

All cast pipe shall be hydrostatically tested to 5,900 p.s.i. and held at that pressure for 20 minutes with zero pipe leakage. Each length of pipe shall be hydrostatically tested at the manufacturer's plant.

The 304L stainless steel shall conform to the following ladle analysis:

Carbon	.03 max.		
Manganese	1.50% max.		
Phosphorous	.03% max.		
Sulphur	.03% max.		
Silicon	2.00% max.		
Chromium	18.00	-	21.00%
Nickel	8.00	-	11.00%

Pipe: All pipe of the following sizes shall be centrifugally cast stainless steel as per ASTM-A 362-52T, except as modified by these specifications:

16" - Sch. #160
12" - Sch. #160
10" - Sch. #160
8" - Sch. #140

All pipe shall be machine finished to 125 micro-inch interior and exterior.

for nuclear piping met by U.S. PIPE metal mold process

Centrifugally Cast Stainless Steel Solves Many Piping Problems

Combinations of temperatures, pressures and corrosive conditions never encountered before: these are among the piping problems that must be overcome by the men who design the nation's nuclear power installations.

Stainless steel centrifugally cast pipe provides many of the answers. Study the specifications at the left . . . specifications demanded of stainless steel pipe on a recent job for Paul Hardeman, Inc., Los Angeles, California. This pipe is being used for heavy duty, high pressure, elevated temperature service in the primary piping system of the SPERT-III Reactor at the U.S. Atomic Energy Commission's National Reactor Testing Station near Idaho Falls, Idaho. The Stearns-Roger Mfg. Company, Denver, Colorado, is the architect-engineer on this project. A complete tabulation of the actual test data obtained on this pipe and to this specification is available upon request.

U.S. Pipe is headquarters for metal mold centrifugally cast alloy and stainless steel pressure pipe over a wide range of special and standard analyses—in large and small quantities—and to individual specifications.

If piping of the type described above is the bottleneck in your nuclear power planning, write and outline the problem.

SIZE RANGE AND COMPOSITION FLEXIBILITY

Outside Diameter—6" to 50"

Wall Thickness—⅜" and up

Length—Up to 16'

Types of Stainless—All Standard AISI and ACI grades of ferritic and austenitic stainless, including No. 20 Alloy, 17-4 P H, 17-7 P H and E.L.C. grades.

UNITED STATES PIPE & FOUNDRY CO.

Steel and Tubes Division

STEEL & TUBES U.S. PIPE DIVISION

BURLINGTON, NEW JERSEY

SALES OFFICES: BURLINGTON, BOSTON, BIRMINGHAM, CHICAGO, CLEVELAND, LOS ANGELES, NEW YORK, PITTSBURGH, SAN FRANCISCO, ST. LOUIS

Assignment: SEA DUTY

Here are more Curtiss-Wright built nuclear controls ready to join the ever-increasing number already in undersea duty.

Already, a total of thirteen ships in the U. S. Navy are either at sea or under construction with Curtiss-Wright controls aboard. More naval submarine rod control, protection and alarm equipment has been built and delivered by Curtiss-Wright than all other manufacturers combined.

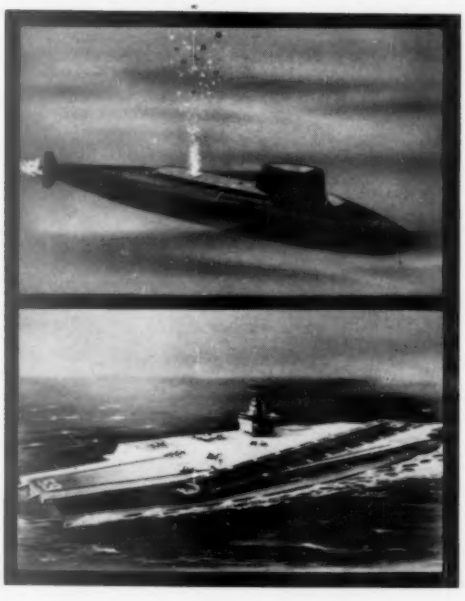
And Curtiss-Wright extruded stainless steel tubing plays an indispensable role in submarine reactor piping. The superior properties that Curmet processing gives to metals have been proved again and again in reactor coolant loop applications.

Such skill and experience are available to help you solve your nuclear problems.

For further information, write: Director of Nuclear Sales, Curtiss-Wright Corporation, Quehanna, Pennsylvania.

CURTISS-WRIGHT

CORPORATION • WOOD-RIDGE, NEW JERSEY



Probably at no time in history has it been more true that the trident of Neptune is the sceptre of the world.

If . . . the enemy could be sure of knocking out every possible land-based retaliatory power of the United States—nuclear carrying planes and missiles—in one fell swoop, it would still have two almost insurmountable obstacles to success; Polaris-armed nuclear subs, hidden away under the ice (possibly in the enemy's own backyard), and nuclear-powered floating airfields, such as the *USS Enterprise*. These are striking forces that will be able to leave port and lose themselves from observation for months on end, standing at the ready at undisclosed attack points.

Solely as defensive, or deterrent, weapons they will offer extra protection for America and the free world. Both of these fearful weapons are under construction at Newport News, the only shipyard under contract for under-sea *and* surface nuclear warships.

For over 70 years a leader in building ships to protect *the freedom of the seas* for America, Newport News is even now becoming a leader in building *nuclear* warships to protect the freedom, not only of the seas, but of Western civilization.

Newport News is the world's most fully integrated shipyard. It will continue to play an increasingly important part in maintaining our way of life.

Newport News

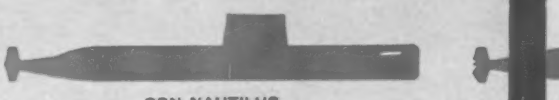
Shipbuilding and Dry Dock Company
Newport News, Virginia

Code: **CGN** . . . Guided-missile Cruiser
CVAN . . . Attack Carrier
DLGN . . . Guided-missile Destroyer
SSN . . . Fleet-type Submarine
SSRN . . . Radar-picket Submarine
SSGN . . . Guided-missile Submarine
SSKN . . . Hunter-killer Submarine
SSBN . . . Ballistic-missile Submarine

CVAN ENTERPRISE

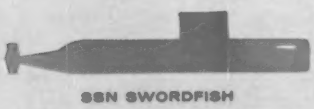
CGN LONG BEACH

DLGN BAINBRIDGE



SSN NAUTILUS

SSN SKATE



SSN SWORDFISH

SSN SARGO

SSN SEADRAGON

SSN SCAMP

SSN SCORPION

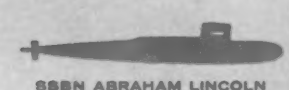
SSN SCULPIN

SSN SHARK

SSN THRESHER

SSN PERMIT

SSKN TULLIBEE



SSBN ABRAHAM LINCOLN

SSBN THEODORE ROOSEVELT

SSBN ROBERT E. LEE

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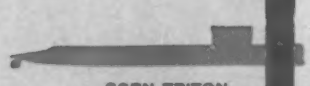
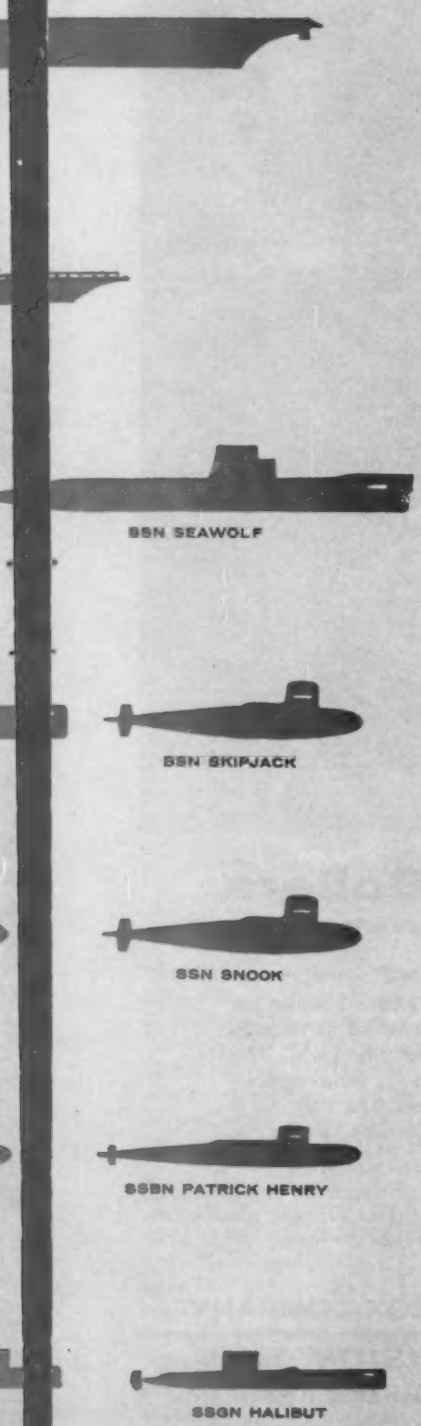


SSRN TRITON



5 years ago

WORTHINGTON ENLISTED IN THE NUCLEAR NAVY

All of the Navy's 25 nuclear vessels in operation or under construction will carry Worthington equipment.

When the Nautilus went to sea in January, 1955, there were several Worthington pumps on board. These included main and auxiliary circulating pumps, main and auxiliary condensate pumps, plus reactor fresh water pumps and other miscellaneous service pumps. From this beginning Worthington has continued to supply the U. S. Navy with vital equipment for nuclear ships. Twenty-five of the twenty-five nuclear ships in operation or under construction, plus 11 authorized by Congress will carry Worthington equipment.

High Pressure Air Compressor for Polaris Ballistic Missile Submarines

The new SSB (N)-598 Class nuclear submarines, of which the recently launched "George Washington" is the first, will go to sea with three Worthington high-pressure, 4500 p.s.i. air compressors on board. A noteworthy "first," these units will furnish pressurized gas to expel the I.R.B.M.'s from their tubes and will also be used for torpedo ejection. At lower pressures, they will be used for water ballast control, low pressure operation of escape hatches and for energizing hydraulic accumulation to operate the periscope, antennae and other mechanisms.

Primary Coolant Pumps (Canned)

Worthington is proud of its part in the development of canned rotor pumps for circulating primary coolant in reactor systems. These motor driven units feature a number of significant design advances.

Reactor Buffer Seal Charging Pumps for N. S. Savannah

Worthington will also go to sea on the first nuclear merchant vessel, the N.S. Savannah. Worthington reactor buffer seal charging pumps are another noteworthy "first" in application and design. As dual purpose units they not only charge the reactor but also provide the vital service of sealing all the reactor control rods.

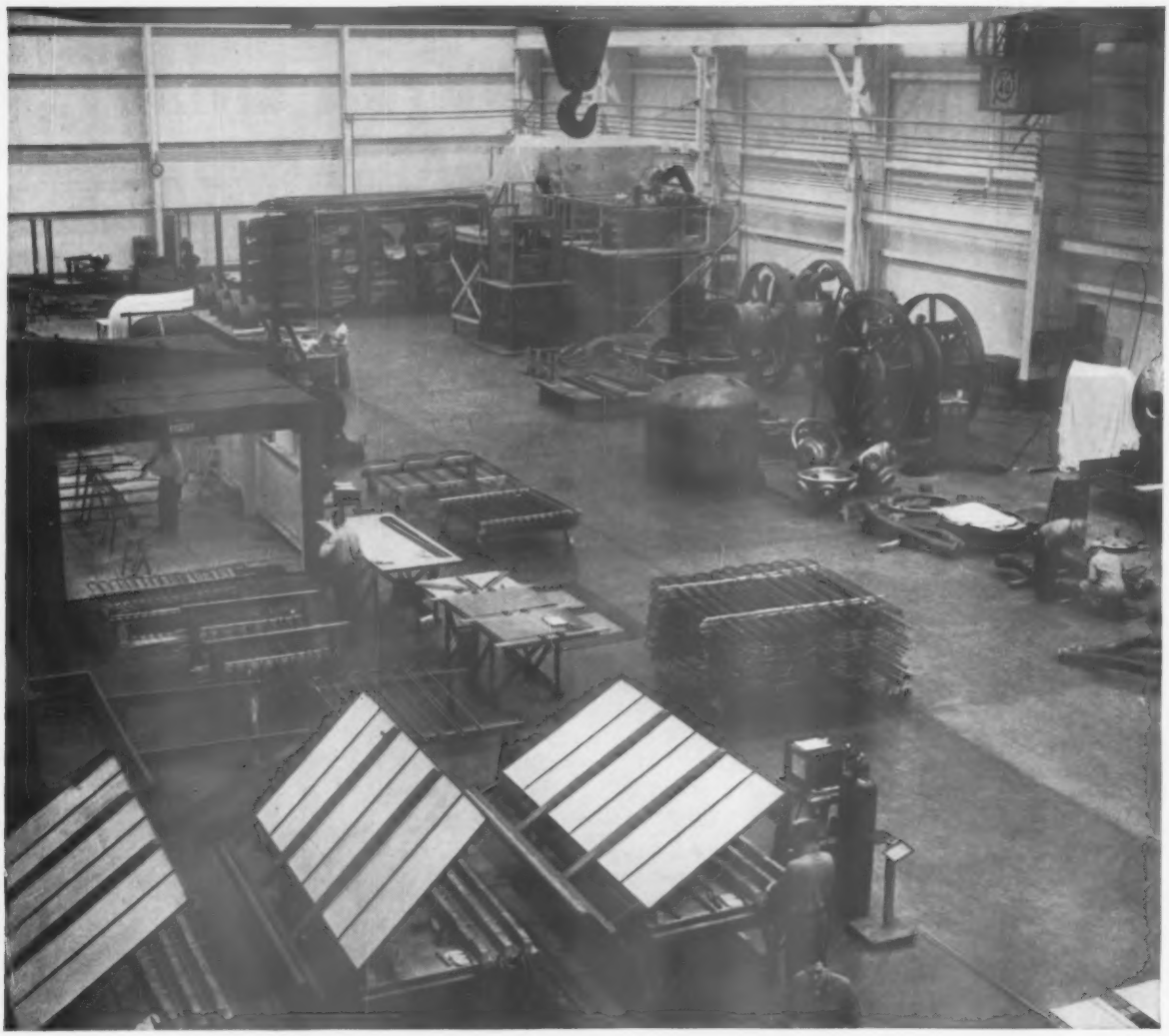
In addition, many other units of secondary cycle and ship's equipment are being built by Worthington.

For more information about Worthington marine products, get in touch with your nearest Worthington district office. Or write to Worthington Corporation, Section 106-4, Harrison, N. J.

WORTHINGTON

MARINE EQUIPMENT BUILT BY WORTHINGTON FOR NUCLEAR VESSELS

- High pressure air compressors
- Low pressure air compressors
- Heat exchangers
- Deaerating feed tanks
- Hydraulic ends for reactor circulating pumps (canned)
- Reactor system charging pumps
- Reactor fresh water pumps
- Decay heat removal pumps
- Circulating pumps
- Condensate pumps
- Drain pumps
- Bilge pumps
- Snorkel de-icing pumps
- Gyro-stabilizer pumps
- Trim & drain pumps
- Distilled plant pumps



Assembly Line For Nuclear Boilers

The careful control required in the fabrication of nuclear boilers has led to the construction of a 22,000 sq. ft. "clean room" at B&W's Barberton, Ohio plant. Here the most modern equipment is housed in an air conditioned building where hospital type conditions assure the highest quality component possible.

B&W nuclear components have been or are being supplied to more than 70 major research or power reactors throughout the world. This experience is available to you . . . your engineering staff . . . your consultants. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

NC-110

B&W

THE BABCOCK & WILCOX COMPANY

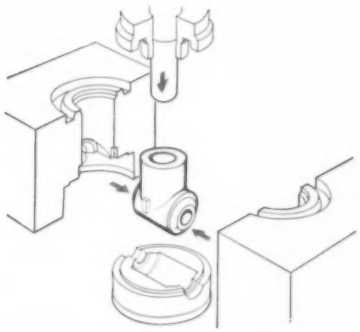
BOILER DIVISION

Complete nuclear systems, cores, components, fuel elements, nuclear research and development

CAMERON SPLIT-DIE FORGINGS FOR NUCLEAR POWER PLANTS

The Cameron split-die process has made ferrous forging history in components for extreme service. These AISI Type 304 stainless steel check valve bodies for nuclear power plants are another chapter in the same story. The Cameron processes were perfectly suited to produce these unusual forgings. Even though test requirements exceeded all normal procedure, we were ready to meet the exacting specifications and complete another forging contract. Most important, performance in end use could be predicted and fear of failure eliminated.

Ferrous forgings to 8,000 lbs. produced by this method emerge from our presses in near final form. A vast array of shapes and sizes, heretofore impossible to forge in one piece, are now solving knotty problems in many demanding applications.

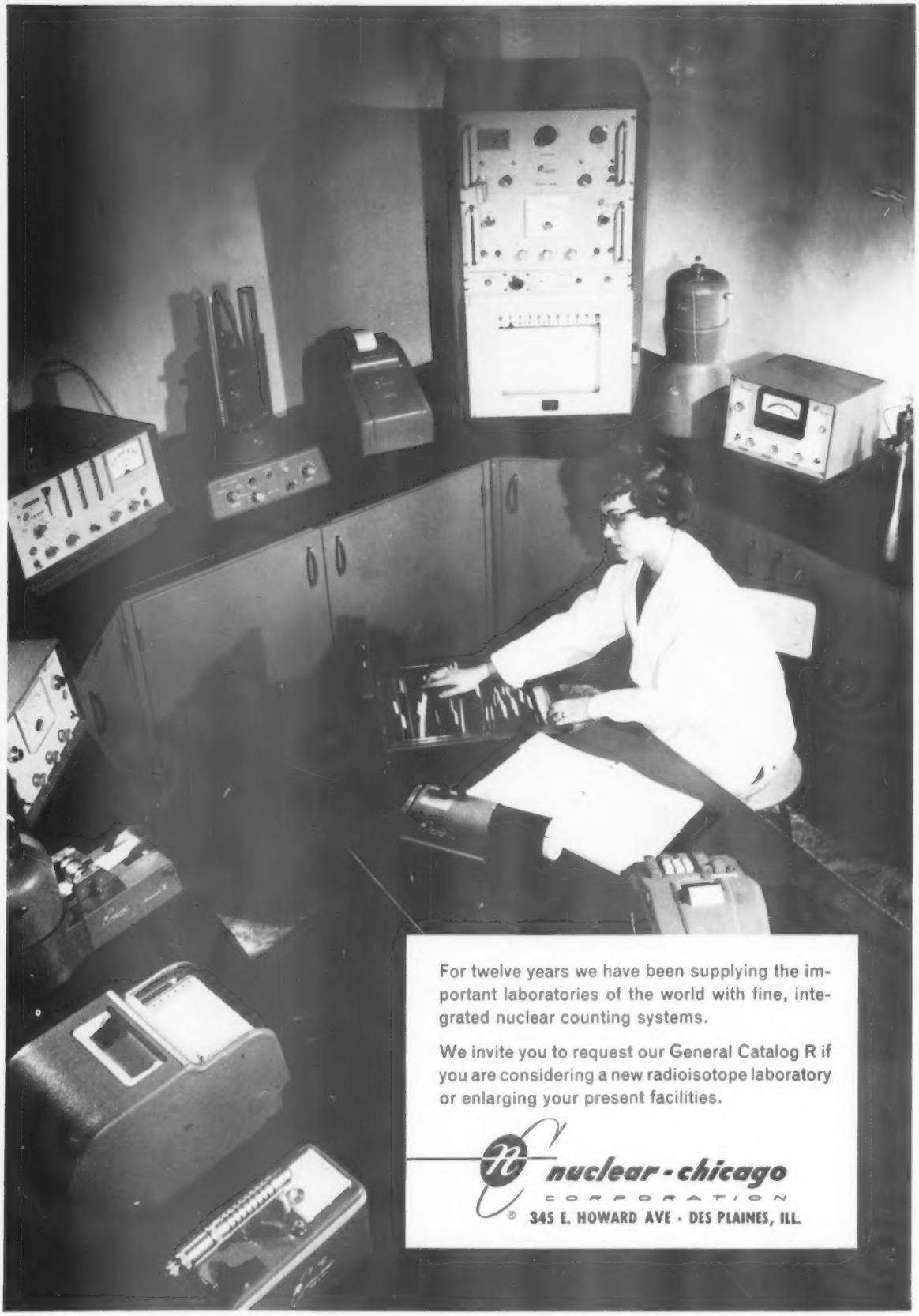


Every single production phase from melting the high quality steels for our ingot supply through blooming, forging and heat treating to final machining is performed in our shops under constant control. Men, instruments and machines are teamed to make results predictable. Grain structures in these remarkable forgings are excellent, welds are eliminated, and machining is made easier. The result is a better component which often costs less.

Extending the design scope of ferrous forgings has made Cameron important in solving many problems which confront advanced design today. Extreme service components for airframes, jet engines, guided missiles and a wide variety of other end uses are finding a solution in the Cameron split-die forging process. If you have a problem . . . call, write or come by

Cameron
IRON WORKS, Inc.

SPECIAL PRODUCTS DEPARTMENT
P. O. Box 1212, Houston, Texas

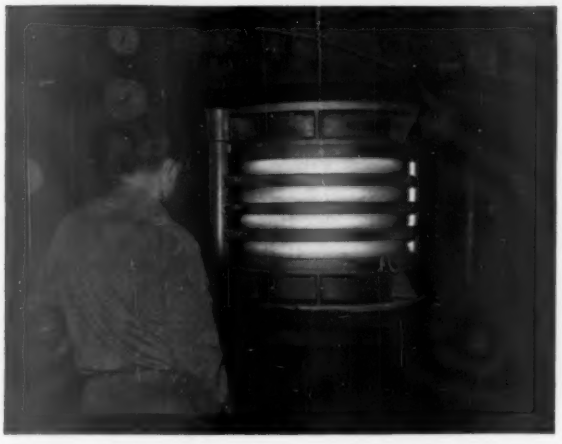


For twelve years we have been supplying the important laboratories of the world with fine, integrated nuclear counting systems.

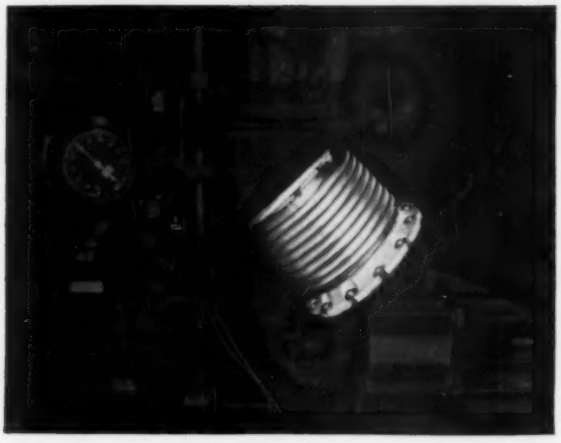
We invite you to request our General Catalog R if you are considering a new radioisotope laboratory or enlarging your present facilities.

nuclear-chicago
CORPORATION
345 E. HOWARD AVE · DES PLAINES, ILL.

4 WAYS to get maximum reliability in expansion joints



1 Insist that the corrugated bellows be hydraulically formed. The reason is simple. Whenever bellows are formed by circumferential welding . . . whether by edge, seam or fillet welding . . . they will always be subject to premature failure because of stress concentrations at the welds.



2 Be sure the manufacturer maintains a continuous and comprehensive program of endurance testing. This is basic, because of the many variables that affect expansion joint life. Accurate determination of expansion joint life expectancy can only be determined by cycling to destruction.

3 Demand proof that the manufacturer can produce longitudinal welds in the corrugated bellows having the same strength, physical properties and thickness as the parent metal . . . without grinding. A weld that is hard to find is a ground weld. Variations in weld thickness set up points of stress concentration . . . opening the way for premature failure.

4 Check the ability of the manufacturer to supply a team of *competent* design and application specialists to work with your engineers. Check their specific experience in handling critical, complex applications in your field . . . complete to the record of successes or failures behind them, and details of how this experience will be brought to bear on your problem.

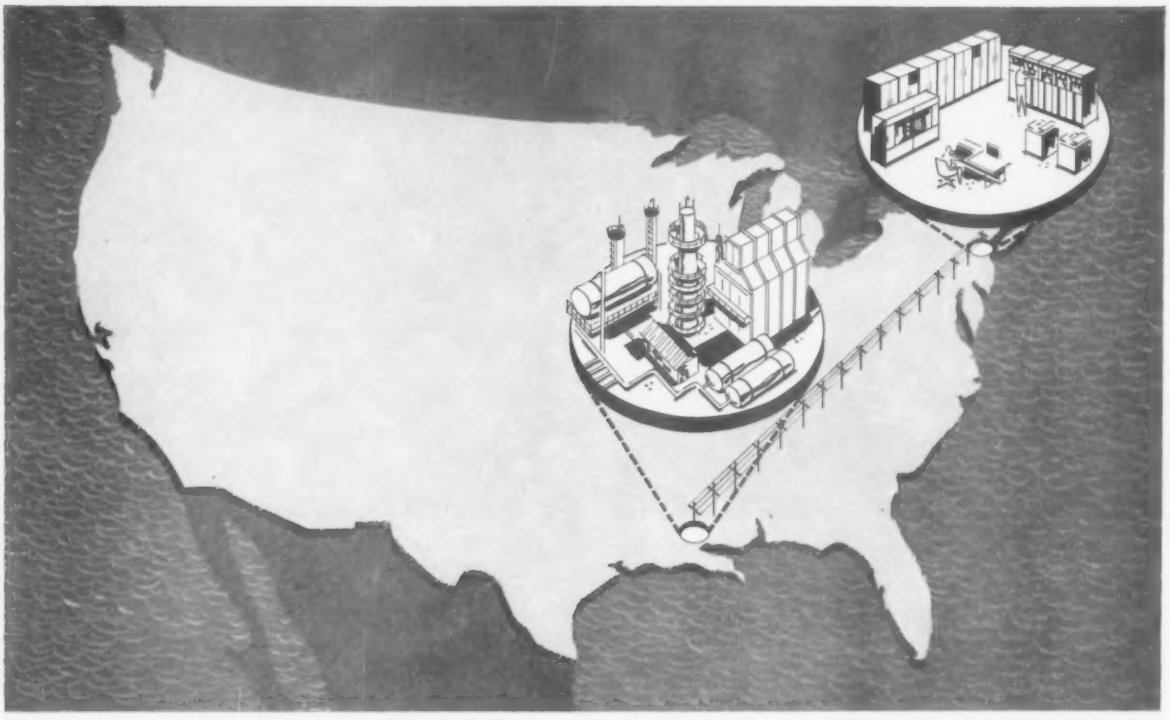
At Zallea, none of the many factors affecting expansion joint reliability are left to guesswork . . . including the four vital ones above.

This is reflected in these facts. Zallea material specifications are the most exacting in the industry. Zallea expansion joints are hydraulically formed. Zallea advanced welding techniques insure welds having the same thickness, strength and physical properties as the parent metal. Zallea has done more cyclic testing to destruction than all government agencies and industrial firms combined. Zallea has produced more expansion joints than any other manufacturer . . . offers more application engineering experience.

For all the facts, write for Catalog 56. Zallea Brothers, Taylor and Locust Streets, Wilmington 99, Delaware.

Zallea for maximum reliability

ZALLEA BROTHERS, Wilmington 99, Delaware • World's largest manufacturer of expansion joints



Now...in addition to on-line computer systems

Operating and test data reduction via telephone link utilizing any computer facility

The new Daystrom TPR Scanning System represents a revolutionary approach with vast implications where there are requirements for immediate or continuous computer analysis of plant operating or test data. The availability of this new tool will influence industry's plans in a number of important areas, which include process studies, experimental test work in the military and nuclear areas, and testing for performance guarantees.

For the first time, the TPR (tape programmed raw) data scanner makes it possible and practical to link a test or operational plant facility directly to any computer in the country for instant computation of data. This is made possible by the utilization of standard telephone communication services, and permits stationing of all engineering and computer programming personnel at the project site, where all phases of the work may be handled.

The importance of this development is brought into sharp focus by the almost non-existence of computer facilities at actual plant or test sites. The utilization of telephone circuits completely circumvents this problem since it makes little difference whether the computer facility to be used is located in an adjoining building, company headquarters or at a rental facility. Distance represents no problem other than nominal telephone service charges.

Telephone communication of this type is a practical reality in the business machine field and is being used every day by leading companies for inventory control, accounting and other purposes. The Daystrom TPR Data Scanner is the first system that has been specifically designed to handle the problems involved in gathering large amounts of analog data peculiar to plant and test facility operation.

The TPR Data Scanner's feature of tape programming provides unlimited flexibility. This permits unrestricted application of the equipment to various types of facilities even though they may be completely different in nature.

Typical of the unequalled performance specifications are 0.1% accuracy at the 99% confidence level, together with extremely high signal to noise ratio at scanning rates up to 40 variables per second. 100% solid state circuitry and full parity checking are incorporated. Input channels may be as few as 100 or as many as 6000.

For further information, write or telephone Daystrom Systems, Dept. A-117, Miramar Road, La Jolla, Calif. GLencourt 4-0421.

Typical 2000 point system delivered to General Electric's nuclear propulsion test group

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DIVISION OF DAYSTROM, INC.

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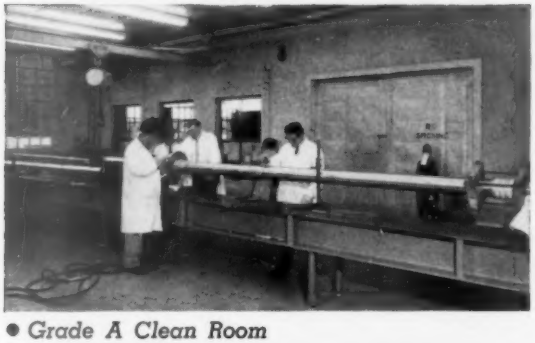
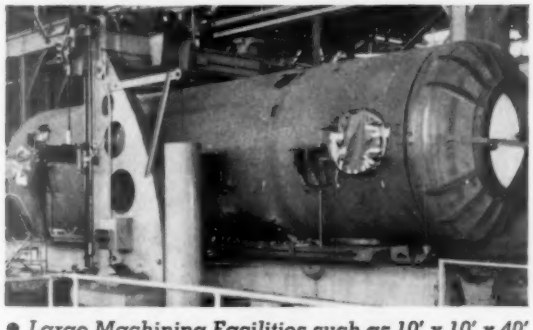


• *Grade A Clean Room*



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available at A. O. Smith. Adaptable to many atom-era fabricating needs, the unique Multi-Layer concept features successive layers of relatively thin steel plate wrapped and seam-welded. Vessel walls can be built to any desired thickness with maximum safety.

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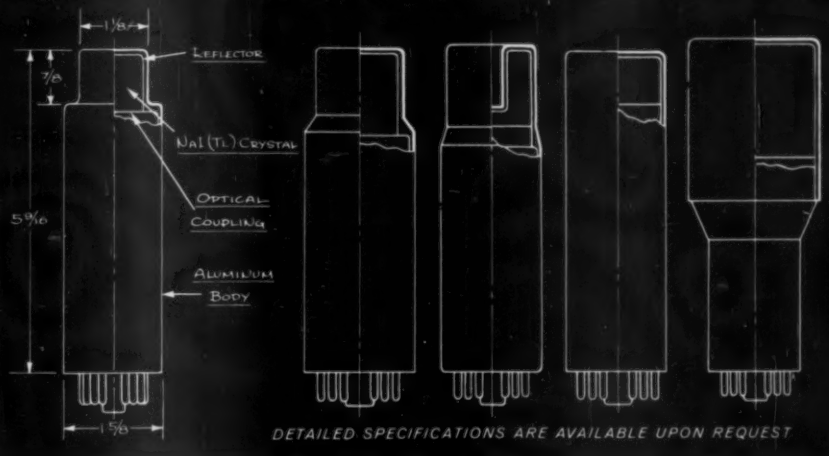

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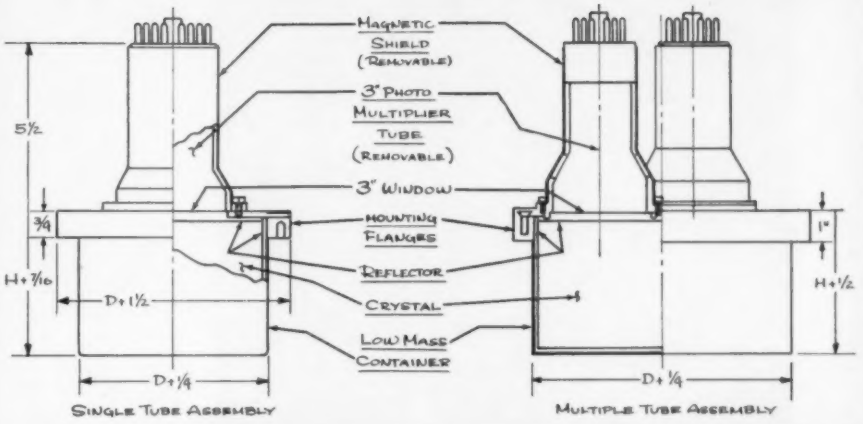

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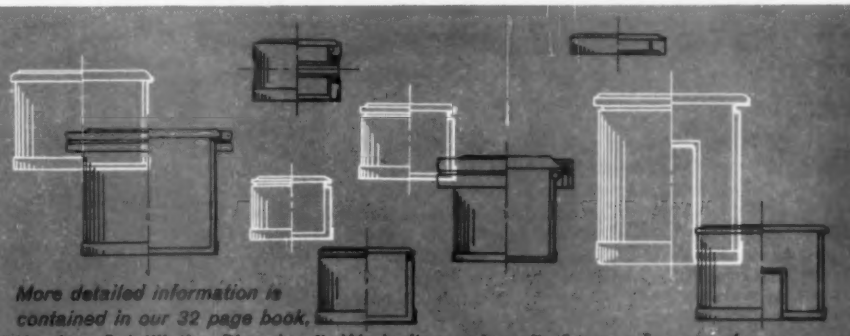

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HARSHAW

PACECO stainless steel reactor vessel, heart of the new Westinghouse Testing Reactor, is pictured during installation at Waltz Mill, Pennsylvania. The new vessel, 30′ long, 7′10″ in diameter, weighing 84 tons, has a head section which is the largest stainless steel casting ever produced. The WTR, a privately owned facility for use by government, industry, universities, and scientific groups, is a thermal neutron reactor, cooled and moderated by light water. Power output, about 20,000 kw heat equivalent; vessel is designed for 110 P.S.I.G. at 135° F.

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PACECO has designed and built equipment for almost every project of the AEC during the past 10 years, as well as several privately financed projects. Let PACECO work for you! Engineering consultation with PACECO at the planning stage may *sharply lower your initial cost.*

PACECO *has supplied atomic projects with*

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CRANES
Custom built, 10- to 400-ton capacity, bridge or circular for special handling

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Photo by General Dynamics

IN THE NAVY'S NEW NUCLEAR FLEET

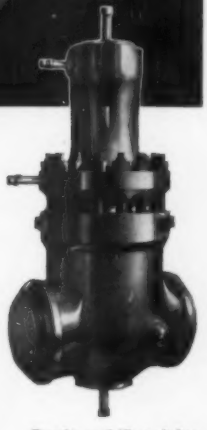
Darling Stainless Steel Valves are "on duty"

Meeting the Navy's rigid specifications for valves in nuclear power plants demands the highest quality and production standards.

Darling is one of the select group of manufacturers supplying stainless steel valves for the Navy's new nuclear submarines. Darling valves are "on duty" on the Skipjack, as well as other nuclear subs still unnamed. These valves incorporate the *exclusive revolving double disc parallel seat* feature... which insures positive sealing and ease of operation.

This Navy acceptance of Darling quality standards holds important implications for designers and builders of commercial atomic power plants. Our know-how and precision manufacturing facilities are at your disposal.

Write us for information, or we'll gladly arrange for a Darling sales engineer to call.



Darling 14" stainless steel gate valve of the type used on the Skipjack.

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Manufactured in Canada by Sandilands Valve Manufacturing Co., Ltd., Galt 19, Ont.

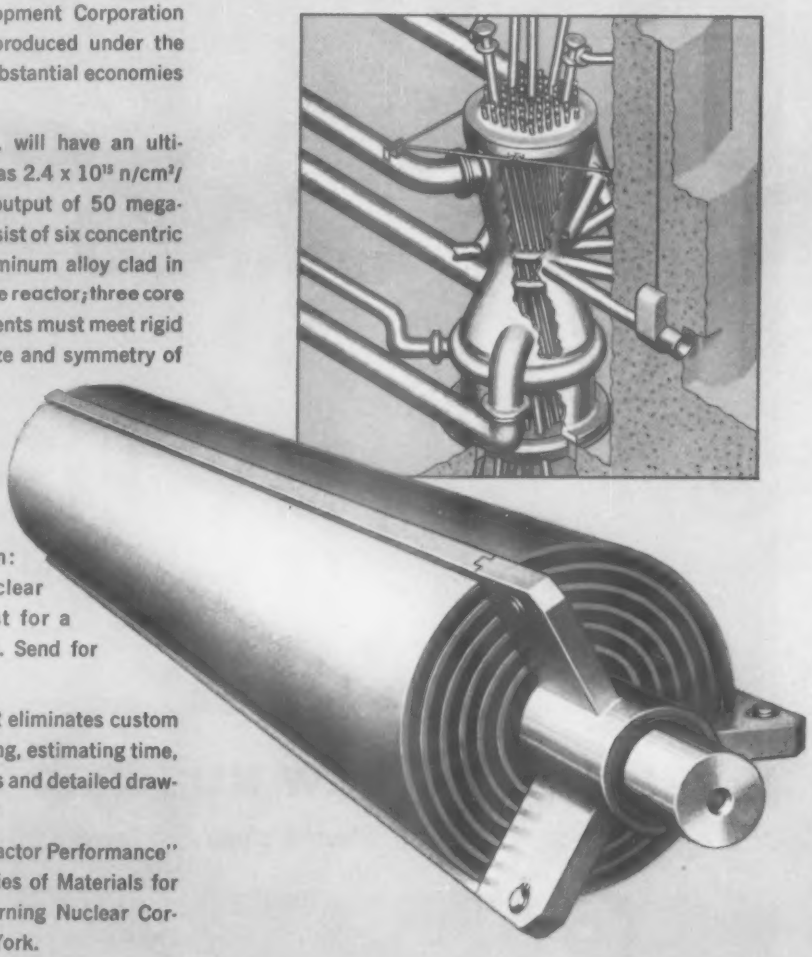
DARLING VALVES

Europe's Highest-fluxed Reactor will be

FUELED by SYLCOR

The Belgian Engineering and Test Reactor, now under construction at Centre d'Etudes pour les Application de l'Energie Nucleaire at Mol, Belgium, is a notable example of joint American-European attainments in the field of nuclear technology. The plant will be of unique and advanced design by Nuclear Development Corporation of America. Fuel elements will be produced under the SYLCOR "Package Fuel" plan with substantial economies to the Belgian government.

The new reactor, designated METR, will have an ultimate epithermal flux density as high as 2.4×10^{15} n/cm²/sec, corresponding with a thermal output of 50 megawatts. The SYLCOR fuel elements consist of six concentric tubes of 90% enriched uranium-aluminum alloy clad in aluminum. 20 such elements will fuel the reactor; three core loadings are being supplied. The elements must meet rigid dimensional tolerances both as to size and symmetry of tubes and water gaps and have been flow-tested at 35 feet per second.



Two recent SYLCOR developments warrant your study in designing or fueling nuclear power plants:

(1) The SYLCOR "Package Fuel" Plan: You obtain your allocation for nuclear material . . . SYLCOR does the rest for a fixed price which is the total charge. Send for information.

(2) Standard Fuel Elements: SYLCOR eliminates custom design, special drafting and engineering, estimating time, special tooling and testing. Data sheets and detailed drawings on four types available.

Write for "Nuclear Fuels: Key to Reactor Performance" and "Physical & Engineering Properties of Materials for Nuclear Fuel Elements." Sylvania-Corning Nuclear Corporation, Bayside, Long Island, New York.

SYLCOR

SYLVANIA—CORNING NUCLEAR CORP.

BUILDING THE NUCLEAR NAVY—1

Navy Makes Great Strides

By JOHN E. KENTON, *News Editor*, NUCLEONICS

NOW IN ITS ELEVENTH year since *Nautilus'* power plant was ordered, the U. S. Navy's vast nuclear propulsion program is still by far the world's biggest power reactor construction program.

Since NUCLEONICS last surveyed the nuclear navy program two years ago (NU, July '57, 66), Congress has augmented the program by 14 submarines and a destroyer-leader. The six nuclear submarines completed have performed spectacularly, setting speed and endurance records and seizing world attention by their trail-blazing Arctic icecap exploits, without a single known instance of reactor-plant breakdown. The submarine program thus looks like this through fiscal 1959:

In operation	5
Decommissioned for reactor change	1
Launched, being fitted out	4
Keels laid, under construction	12
Assigned to shipyards, to be laid down soon	11
	33

The Navy's first surface ship, the cruiser *Long Beach*, has been launched; assembly of the hull of the eight-reactor aircraft carrier *Enterprise* has reached the main, or hangar, deck; and the destroyer-leader *Bainbridge's* keel has been laid. Driving these 36 vessels through the seas will be 46 reactors.

And as this issue goes to press, Congress has just voted the fiscal-1960 defense appropriation carrying authorization for four nuclear attack submarines, and advance procurement of long-lead-time items (e.g. reactor pressure vessels, turbines) for a second nuclear carrier (probably with four improved reactors) and three more Polaris-firing subs to be funded in fiscal 1961. These eleven additional reactors bring the grand total of seagoing naval reactors to 57 not counting the six land-based prototypes. (Total 61 if the new carrier gets eight reactors.)

Since the program began in 1948, the Navy has spent or committed an estimated $3.1-billion on nuclear construction, and AEC another $495-million (*see table*).

Perhaps the most significant development in the last two years has been the unqualified success on her trials of *Skipjack*, the Navy's sixth nuclear submarine and first to combine nuclear propulsion with the streamlined *Albacore* hull design. Her resounding success vindicates the Navy's choice, even before it was tested, of her S5W reactor plant to be history's first mass-produced power reactor. In a major step toward standardization, this third-generation (descendant of *Nautilus* and *Skate* reactors) pressurized-water plant is also being used to power the Polaris-firing submarines; no less than 27 have been ordered so far, with seven more now in the offing.

Similarly, the cruiser and carrier will be powered by like reactors: although the two in *Long Beach* are designated C1W and the eight in *Enterprise* A2W, these are essentially identical.

Although the roster of nuclear ships authorized and the scope of the entire program is still growing rapidly, the slope of its growth curve has been somewhat less steep than Navy leaders hoped and predicted two years ago. This is due only partly to technical progress being slower than

AEC Share of Naval Propulsion Reactor Costs (10^6)

Fiscal year	*Research & development*	*Construction*	*Total*
1948–50	8.7	0.1	8.8
1951	22.2	7.6	29.8
1952	26.1	11.9	38.0
1953	32.9	24.4	57.3
1954	24.9	24.1	49.0
1955	26.8	12.9	39.7
1956	40.9	9.8	50.7
1957	79.1	26.0*	105.1
1958	81.9†	34.9	116.8
Totals	343.5	151.7	495.2

* Plus "a charge of $20.5-million resulting from retirement of the obsolete prototype of the sodium reactor developed for *Seawolf*." (AEC Financial Report, 1958.)

† "Beginning in fiscal 1958 certain costs incurred in the fabrication of reactor fuel were included in inventory; during fiscal 1958 these costs totaled $15-million." (AEC Financial Report, 1958.)

1959 Progress Report on the Nuclear Navy

Ship-bldg. Program Year	Ship No.	Ship Name	Shipyard	Reactor Type	Reactor Design	Dimensions Displ. tons—Length—Beam	Date (*Future target dates in italics*) Keel laid	Launch	Compl.	Cost 10^6
1952	SSN 571	NAUTILUS	Electric Boat	S2W	W	3,180 — 320 — 28	6-14-52	1-21-54	9-30-54	90
1953	SSN 575	SEAWOLF	Electric Boat	S2G S2W-A	GE W	3,260 — 330 — 30	9-15-53	7-21-55	3-30-57 *6- 1-60*	94 +20
1955	SSN 578	SKATE	Electric Boat	S3W	W	2,360 — 268 — 25	7-21-55	5-16-57	12-23-57	50
1955	SSN 579	SWORDFISH	Portsmouth	S4W	W	2,360 — 268 — 25	1-25-56	8-27-57	9-15-58	50
1956	SSN 583	SARGO	Mare I.	S3W	W	2,360 — 268 — 25	2-21-56	10-10-57	10- 1-58	45
1956	SSN 584	SEADRAGON	Portsmouth	S4W	W	2,360 — 268 — 25	6-20-56	8-16-58	*12- 1-59*	45
1956	SSN 585	SKIPJACK	Electric Boat	S5W	W	2,830 — 252 — 29	5-29-56	5-26-58	4-15-59	65
1956	SSRN 586	TRITON	Electric Boat	S4G	GE	5,900 — 447 — 37	5-29-56	8-19-58	*9-30-59*	104
1956	SSGN 587	HALIBUT	Mare I.	S3W	W	3,555 — 350 — 29	4-11-57	1- 9-59	*12-30-59*	65
1957	SSN 588	SCAMP	Mare I.	S5W	W	2,830 — 252 — 29	1-23-59	*2-15-60*	*12-30-60*	50
1957	SSN 589	SCORPION	Electric Boat	S5W	W	2,830 — 252 — 29	8-20-58	*11- 1-59*	*5- 1-60*	50
1957	SSN 590	SCULPIN	Ingalls	S5W	W	2,830 — 252 — 58	2- 3-58	*10-31-59*	*7-18-60*	50
1957	SSN 591	SHARK	Newport News	S5W	W	2,830 — 252 — 29	2-24-58	*3- 3-60*	*12-30-60*	50
1957	SSN 592	SNOOK	Ingalls	S5W	W	2,830 — 252 — 29	4- 7-58	*4-16-60*	*12-30-60*	50
1957	SSN 593	THRESHER	Portsmouth	S5W	W	3,747 — 278 — 31	5-28-58	*3- 5-60*	*12-30-60*	60
1958	SSN 594	PERMIT	Mare I.	S5W	W	3,747 — 278 — 31	7-16-59	*9- 1-60*	*8-31-61*	50
1958	SSN 595	PLUNGER	Mare I.	S5W	W	3,747 — 278 — 31	*12-31-59*	*4- 1-61*	*3- 1-62*	50
1958	SSN 596	POLLACK	Ingalls	S5W	W	3,747 — 278 — 31	*11- 9-59*	*6-17-61*	*4-20-62*	50
1958	SSN 597	TULLIBEE	Electric Boat	S2C	CE	2,175 — 260 — 29	5-26-58	*3- 1-60*	*8-15-60*	75
1958	SSBN 598	GEORGE WASHINGTON	Electric Boat	S5W	W	5,600 — 380 — 32	11- 1-57	6- 9-59	*12-31-59*	110
1958	SSBN 599	PATRICK HENRY	Electric Boat	S5W	W	5,600 — 380 — 32	5-27-58	*9-22-59*	*3-31-60*	100
1958	SSBN 600	THEODORE ROOSEVELT	Mare I.	S5W	W	5,600 — 380 — 32	5-20-58	*10- 2-59*	*6-30-60*	100
1959	SSBN 601	ROBERT E. LEE	Newport News	S5W	W	5,600 — 380 — 32	8-25-58	*12-18-59*	*9-30-60*	100
1959	SSBN 602	ABRAHAM LINCOLN	Portsmouth	S5W	W	5,600 — 380 — 32	11- 1-58	*4- 2-60*	*12-30-60*	100
1959	SSN 603	BARB	N. Y. Shipbldg.	S5W	W	3,747 — 278 — 31	*11-30-59*	*6- 3-61*	*4- 1-62*	50
1959	SSN 604	HADDO	N. Y. Shipbldg.	S5W	W	3,747 — 278 — 31	*3-28-60*	*9-30-61*	*8- 1-62*	50
1959	SSN 605	JACK	Portsmouth	S5W	W	3,747 — 278 — 31	*3-23-60*	*11-18-61*	*10- 1-62*	50
1959	SSN 606	TINOSA	Portsmouth	S5W	W	3,747 — 278 — 31	*11-24-59*	*7- 1-61*	*5- 1-62*	50
1959	SSN 607	DACE	Ingalls	S5W	W	3,747 — 278 — 31	*2- 8-60*	*1-10-62*	*9-20-62*	50
1959	SSBN 608	ETHAN ALLEN	Electric Boat	S5W	W	5,900 — 410 — 33	*9-15-59*	*11- 1-60*	*6-30-61*	105
1959	SSBN 609	Unnamed	Newport News	S5W	W	5,900 — 410 — 33				105
1959	SSBN 610	Unnamed	Electric Boat	S5W	W	5,900 — 410 — 33				105
1959	SSBN 611	Unnamed	Newport News	S5W	W	5,900 — 410 — 33				105
1960	SSN 612	Unnamed	Unassigned	S5W	W	3,747 — 278 — 31				49
1960	SSN 613	Unnamed	Unassigned	S5W	W	3,747 — 278 — 31				49
1960	SSN 614	Unnamed	Unassigned	S5W	W	3,747 — 278 — 31				49
1960	SSN 615	Unnamed	Unassigned	S5W	W	3,747 — 278 — 31				49
1957	CGN 9	LONG BEACH	Beth. Quincy	C1W	W	14,000 — 690 — 70	12- 2-57	7-14-59	*spring '61*	150
1958	CVAN 65	ENTERPRISE	Newport News	A2W	W	86,000 —1,102 — 133	2- 4-58	*July '60*	*late '61*	435
1959	DLGN 25	BAINBRIDGE	Beth. Quincy	D2G	GE	7,900 — 550 — 56	5-15-59	*late '60*	*late '61*	105
1961	CVAN 66	Unnamed	Unassigned	—	—	76,000 —1,047 — 130				380

Navy reactor designations have one letter indicating type of vessel (S = submarine, A = aircraft carrier, C = cruiser, D = destroyer-leader [frigate]), one number indicating the order of construction of the reactor type, and one letter for the manufacturer's initial (W = Westinghouse, G = General Electric, C = Combustion Engineering). Ship designations are: SSN = Submarine, nuclear [attack type], SSRN = Submarine, radar-picket, nuclear; SSGN = Submarine, guided-missile, nuclear; SSBN = Submarine, ballistic-missile, nuclear; CGN = Cruiser, guided-missile, nuclear; CVAN = Aircraft Carrier, attack,

expected in reducing weight-to-horsepower ratio. Mostly it is a matter of budgetary policy. The Administration's determination to maintain what it calls "fiscal soundness" —with an assist from House Appropriations Committee chairman Clarence Cannon (who is opposed, on principle, to aircraft carriers)—forced the Navy to give up its plan for building five additional nuclear carriers. Instead of starting one each year from 1959 through 1963, the Navy will settle instead for building a carrier every other year. And in spite of bills in Congress calling for construction of 100 Polaris-firing submarines, the Navy has not yet reached the goal of building 12 a year but has been getting them in increments of only three to five a year. (This year, for example, the Budget Bureau allowed only three of the Navy's bid for eight nuclear subs—Congress made it four.)

The Navy's Nuclear Policy

The Navy hopes to have a complete nuclear task force started by 1964, the Navy's top leader, Chief of Naval Operations Admiral Arleigh A. Burke, told NUCLEONICS. He set forth the Navy's policy on nuclear construction:

"If it were not for considerations of economy, we would be building nuclear power into all ships in which it is technically feasible to do so. At the present time this includes

and on its Suppliers

NOTE: Data on components for submarines in the 1957, 1958 and 1959 programs are correct as regards number of items ordered from each supplier, but are subject to changes in ship-assignment with variations in construction schedules

Core	Press. Vessel	Steam Gen.	Pressurizer	Main Coolant			Rod drive Mechanisms	Reactor Rod Controls	Reactor Instrumentation	Primary Plant Instrum.	Steam Gen. Control	Turbine
				Pumps	Stop Valves	Check Valves						
W	B & W	2 FW	B & W	W	Chapman	Atw'd-Morrill	W	W	W	W	Bailey	W
GE	CE	2 B & W	none	GE	Crane	GE	Ford Instrum.	GE	GE	GE	Bailey	GE
B & W	B & W	2 FW	FW		Crane	W		W	W	W	W	
W	W	2 W	CE	W	W	Atw'd-Morrill	Bendix	W	W	W	Swartout	W
W	W	2 W	CE	W	W	Atw'd-Morrill	Bendix	W	W	W	W	W
B & W	B & W	2 CE	CE	W	Crane	Atw'd-Morrill	Bendix	W	W	W	Swartout	W
W	B & W	2 W	CE	W	Crane	Atw'd-Morrill	Bendix	W	W	W	W	W
W	B & W	2 B & W	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Curtiss-Wright	W	W	W	W
2 M & CN	2 CE	4 CE	2 B & W	W	Crane	Walworth	Borg-Warner	GE	Dumont	GE	GE	GE
W	B & W	2 W	CE	GE	Crane	Atw'd-Morrill	Bendix	W	W	W	W	W
W	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Curtiss-Wright	W	W	W	GE
W	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Aerojet-General	W	W	W	GE
CE	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Thompson	Aerojet-General	W	W	W	GE
M & CN	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Thompson	Aerojet-General	W	W	W	GE
OM	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Thompson	Aerojet-General	W	W	W	GE
CE	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Thompson	Aerojet-General	W	W	W	GE
W	B & W	2 CE	FW	W	Crane	Atw'd-Morrill		Aerojet-General	Daystrom	Consol.	W	W
OM	B & W	2 CE	CE	W	Crane	Atw'd-Morrill			Daystrom	Consol.	W	W
OM	B & W	2 CE	CE	W	Crane	Atw'd-Morrill			Daystrom	Consol.	W	W
CE	CE	2 CE	Alco	W	Crane	Atw'd-Morrill	Borg-Warner	GE	W	W	W	W
M&CN	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Curtiss-Wright	Daystrom	Consol.	Vickers	GE
CE	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Curtiss-Wright	Daystrom	Consol.	Vickers	GE
	B & W	2 FW	FW	W	Crane	Atw'd-Morrill	Borg-Warner	Curtiss-Wright	Daystrom	Consol.	W	GE
	B & W	2 FW	FW	W	Crane	Atw'd-Morrill		Curtiss-Wright	Daystrom	W	W	GE
	B & W	2 B & W	FW	W	Crane	Atw'd-Morrill		Curtiss-Wright	Daystrom	W	W	GE
	B & W	2 B & W	CE	W	Crane	Atw'd-Morrill			W	W	W	GE
	CE	2 B & W	CE	W	Crane	Atw'd-Morrill			W	W	W	GE
	CE	2 B & W	CE	W	Crane	Atw'd-Morrill			W	W	W	GE
	CE	2 B & W	FW	W	Darling	Atw'd-Morrill			W	W	W	DeLaval
	B & W	2 B & W	FW	W	Crane	Atw'd-Morrill			W	W	W	W
	B & W	2 B & W	FW	W	Crane	Atw'd-Morrill			W	Vickers	W	GE
	B & W	2 B & W	CE	GE	Crane	Atw'd-Morrill			W	Vickers	W	W
	B & W	2 B & W	CE	GE	Crane	Atw'd-Morrill			W	W	W	GE
	B & W	2 B & W	CE	GE	Crane	Atw'd-Morrill			W	W	W	W
2 W	2 CE	8 FW	2 Alco	GE	Crane, Chapman	Hammel-Dahl	Bendix	Ward-Leonard	W	W	GE	2 GE
4 OM, 2 W, 2 M & CN	2 FW, 6 CE	16 W, 16 FW	4 FW, 4 Alco	16 GE 16 W	32 Crane, 32 W	32 Atwood-Morrill	United Shoe, Vard	W	W	Vickers	GE	8 W
	2 CE	6 FW	2 Alco	W	Crane	Atw'd-Morrill	United Shoe	GE	Bendix	Consol., W	W	2 GE

nuclear; DLGN = Destroyer leader, guided-missile, nuclear

Company abbreviations:
B & W = Babcock & Wilcox
CE = Combustion Engineering
FW = Foster Wheeler
GE = General Electric
M & CN = M & C Nuclear
OM = Olin Matheson
W = Westinghouse
Consol. = Consolidated Control Corp.

all submarines and the carrier, cruiser and [frigate, or] destroyer-leader* type surface ships. We would like to put nuclear power into the smaller destroyer and escort ships when we can get power plants into a small enough package.

"However, we do have the economic consideration today. Consequently our present policy is to build all nuclear-powered submarines, and work toward building a nuclear-powered surface task force as soon as economically feasible.

"Our problem is to incorporate as many of the new technical improvements into new-construction ships as possible and still maintain the costs at a level which will permit adequate replacement of obsolete and over-age ships in the Fleet today. We must evaluate the relative advantages of new missile systems, improved sonar, radar, tactical data systems and nuclear power, as well as the impact on future operating costs.

"We hope to have a nuclear task force† authorized within the next five years."

By late 1961 the Navy will have in operation one nu-

* In U. S. Navy parlance, "destroyer-leader" and "frigate" are equivalent names for an over-size destroyer. *Bainbridge* at 7,900 tons is bigger than many warships rated light cruisers.

† The average fast carrier task force includes two carriers, two cruisers, twelve destroyers.

clear-powered unit of each surface-ship type comprising a fast-carrier task force: a carrier, cruiser, and destroyer leader. "Our experience with these ships," Admiral Burke says, "may well cause us to accelerate our nuclear-surface-ship building program."

Meanwhile there are two things the Navy must do: reduce cost, and reduce weight-to-horsepower ratio. "The cost-per-mile has come down some," Admiral Burke comments, "but the cost per plant has not come down nearly as much as it will have to. We haven't been able to bring them down as fast as I thought we could, and still retain the safety factor we want to retain."

Admiral Burke's guardedness about cost-per-mile improvement notwithstanding, the advances reported on this front have been, if anything, on the dramatic side. When *Nautilus* burned out her second core in June, she had traveled 93,000 miles on it, as compared with 62,000 on her first. And Vice Admiral H. G. Rickover, in charge both at the Navy and AEC of building our nuclear fleet, told Congress in June that "we are now building cores that will give us 50% more life than even this second core." That would be 139,500 miles, or 225% better than the first *Nautilus* core. Since this is obtained without increase in cost (except for burnup of more uranium)—because the relatively stable core-fabrication cost is the main cost involved—it follows that the cost-per-mile must have come down by a like percentage. As Rickover puts it, "The cost reduction of the core-per-mile-steamed pretty much corresponds to the increase in full-power life because it costs very little more, for example, to fabricate a core which can make 4,000 full-power hours than to make one which runs 2,000."

FIGHTER A-SUB prototype, *Skipjack*, seen at full speed on surface—where she won't be seen often

BOMBER A-SUB prototype, *George Washington*, at her launching displays sting-packing hump aft

The Navy's eventual aim is to develop cores that will last the life of the ship, so that one *never* need refuel. Right now the Naval Reactors Branch is working toward cores that would last 4–5 years. "Our experience with *Nautilus* has been such that we can expect to use up the equivalent of about 1,000–1,500 full-power hours a year," Rickover says. "This means that a nuclear-powered destroyer or frigate with a nuclear core having a capacity of 5,000 full-power hours and operating as much as *Nautilus* has operated would not need to be refueled for several years. We are approaching the point where we will have reactors we can put on a ship which will last for an entire [World-War-II length] war. This is our objective."

At present, our most recently started surface ship of the three building, the frigate *Bainbridge*, will be able to steam 100,000–150,000 miles continuously at full power on her first fuel charge, as compared with only 2,000 miles for an oil-fired frigate. So although the nuclear frigate costs $40-million more than an equivalent conventional one, the A-ship's capital cost includes its fuel bill for its first 3–4 years of operation.

Generally, the capital cost today for a nuclear-propelled ship, any type, is about 75% more than for an equivalent oil-fired, Rickover estimates. Fuel cost is still 7–8 times greater, he says—but points out that the nuclear ship eliminates tankers and other logistic support.

Construction Outlook

In trying to assess the market for naval reactors over the next few years, one runs into two intangibles. One is the unpredictability of the Washington political climate regarding the defense budget. The other question-mark—to which a firm answer is more easily provided—has to do with the performance of the prototype nuclear surface ships now building. For, great as are the advantages of nuclear power for surface ships (vastly extended range; fuel-bunker space freed for carrying more aviation gas, ammunition, or gear; heightened resistance to nuclear attack because absence of stacks permits sealing ship, etc.), they are not as clearcut as the overwhelming advantage for submarines: liberation from the surface. Consequently the Navy is moving into nuclear surface ships cautiously; it wants to test *Long Beach* and *Bainbridge* in action thoroughly and evaluate their real capabilities carefully before committing itself to wide or exclusive use of nuclear power in surface ships at a time when the extra cost of the atom makes it still a luxury for a tight budget. Even so, one of Admiral Burke's top aides, told Congress a year ago, "Nothing but nuclear-propelled new cruisers for our future Navy."*

* Navy appropriation requests this year were for a conventional carrier on the ground that the Navy had more urgent uses for the $120-million incremental cost of nuclear power for a carrier, although Dissenter Rickover told Congress, ". . . to buy an obsolescent ship is stupid. . . . I do not care what arguments are given to you." The Senate agreed with him and voted the atomic carrier.

GUIDED-MISSILE SUB *Halibut* enters fitting-out basin; note bulging sides forward where Regulus hangars are located

RADAR-PICKET SUB *Triton* after her launch; her radar-antenna-loaded conning tower is as long as Navy's first sub, USS *Holland*

According to present Navy plans, in addition to the nuclear carrier every other year with larger numbers of smaller ships requested in the off-years, the Navy hopes to build up to a force of about 75 attack-type subs and 40–50 Polaris-firing ones by 1970.

In these aims the Navy has an ally in Rep. George H. Mahon, chairman of the Defense Appropriations subcommittee of the House Appropriations Committee. Mahon told NUCLEONICS that although he expected defense spending to remain fairly constant over the next few years (barring increases in international tension), Congress might well again add ships to the Administration's program, as it did last year. "The Executive branch is shying away from full application of nuclear power to the Navy to a reasonable maximum," he said.

The New A-Sub Fleet

Together with selection of the S5W plant as the standard sub reactor has come a narrowing of submarine types down to two: the Polaris-firing FBM (Fleet Ballistic Missile) craft, and the *Skipjack*-type attack sub, now assigned anti-sub duties. Although Navy Secretary Franke told NUCLEONICS no decision would be made until after thorough testing of *Triton*, the radar-picket sub, and *Tullibee*, the hunter-killer sub, many high operating officers admitted they did not look to see any more built like these two. *Halibut*, the guided-missile sub, also became one-of-a-kind with the cancellation of the Regulus-II missile program; the four follow ships authorized will be built as *Skipjack*-types instead.

A rundown of the A-sub roster discloses some interesting developments in nuclear propulsion technology.

Nautilus is presently undergoing her second refueling and first major overhaul at Portsmouth (N. H.) Naval Shipyard. The job, begun in June and scheduled to take nine months (although the yard hopes to do it in less), will include dismounting of her pumps, turbines, etc. for examination—in fact, "exploration of all her existing machinery to derive the maximum knowledge from her very reliable operation to date." As Bureau of Ships Chief Rear Adm. Ralph K. James told NUCLEONICS, "She's not only a very effective fleet boat but also a floating nuclear laboratory. Now we'll see what else she can teach us." Portsmouth, although having already completed one A-sub (*Swordfish*) and building five others, had to train welders especially for the massive welding jobs involved in *Nautilus'* refueling. The shipyard ran a dry-run refueling on a dummy for training purposes.

The new core is expected to have an even longer life than the second, but this will have no effect on her speed; the parameters such as flow-rate and temperature rise across the core (33° F) will be identical. "I could get more power out of this [second] core but the steam plant is built for a given rating," *Nautilus'* former skipper, Cdr. W. R. Anderson, told NUCLEONICS. "The limiting factor on *Nautilus* is the design of the steam plant."

Seawolf is getting not just a new core, but a whole new reactor. She was decommissioned last December after having gone 71,609 miles on her first core. Her sodium-cooled intermediate-neutron reactor primary parts, encased in a specially-built shielded barge, were sunk in the Atlantic; the core went to Idaho for study. *Seawolf* is now being outfitted, at Electric Boat's yards where she was built, with a copy of *Nautilus'* water reactor—in fact her new power plant incorporates many of the pieces originally ordered for *Nautilus* as dockside spares, including the pressure vessel. She is expected to be back at sea next spring.

Looking back on the *Seawolf* experience, her builders, officers, and the Navy feel that—after the early superheater troubles were licked (NU, July '57, 70)—it demonstrated not only the fine performance of the sodium reactor, which never gave the slightest trouble in two years of operation, but also proved the feasibility of building an inherently-reliable, sealed package of nuclear power requiring no maintenance at sea. However the Navy is not now actively pursuing this approach; on the contrary, for water reactors the ability to repair at sea is assumed to be a part of ship capability, even though designing in accessibility adds shielding weight which decreases performance. Incidentally, *Seawolf* is reported to have had extremely low operating costs because of her reactor's amazing performance (the reactor compartment was never entered during the 23 months *Seawolf* was operational).

Skate has been in service almost two years on her first core; two of her sisters, *Sargo* and *Swordfish*, put to sea more recently. *Seadragon*, last of the quartet nearing completion at Portsmouth, was delayed six months by a shortage of skilled help. Although *Skate's* Arctic pioneering was acclaimed in the press, the Navy has not yet announced that *Sargo* has been to Antarctic waters—only

that she sailed from the Golden Gate Jan. 11 and steamed 19,000 miles in the Pacific, to Pearl Harbor and then across the Equator, returning to San Francisco Bay April 3, having been submerged for 18,900 miles—99.5% of the time. (An average conventional sub runs about 18,000 miles in a whole year, 75% of the time on the surface.)

The *Skate*-class embodies the S3W-S4W experiment in shielding configuration (regular shield deck vs. shielded crew passageway). As to which is proving more satisfactory, it's said that, so far, "it comes out about the same."

One ground rule in designing the S3W reactor was to be able to refuel element by element, without pulling the pressure-vessel head. *Nautilus'* cores have all been rigidly bolted together. A new head for *Nautilus'* vessel to give her this capability is under study.

Halibut, the sub built around a capacious missile hangar, is due to go to sea before the year is out.

Triton, once described as a radar-picket destroyer with incidental ability to submerge, is a sub so big that when she dives she gulps into her ballast tanks the weight of water that an entire World War II sub displaced. The only sub with two reactors, hers are General Electric's first venture into pressurized water. Each is rated at higher power output than previous submarine reactors; they are so designed that individual fuel elements can be removed and replaced, possibly by a submarine tender, away from home navy yards. *Triton's* are the only naval reactors not using plate-type fuel elements, but a novel configuration. Built to keep up with a fast carrier task force, this floating island of electronics must be capable of 32–33 knots surfaced or submerged, carrying her huge radar antennae that retract into the sail. The Navy sees her as also paving the way for the large subs of the future. She is due to start her trials this month. Expected range on first cores: 110,000 mi.

Tullibee started life as a sub-hunter-killer specialist, lost the distinction when all attack subs came to be regarded as anti-sub subs as well as surface-ship killers. In one sense, no matter how successful she proves in operation, she is already a failure: she was to have been the pioneer nuclear-propelled *small* sub, but her weight came out to be only 185 displacement tons less than *Skate*, her length 8 ft longer than *Skipjack*. This is by no means entirely due to reactor or shielding problems, but to the irreducibility of turbines and gears, controls, sonar, torpedoes, berthing space, etc. *Tullibee* is now regarded as an experiment in quiet operation, increased use of sound gear, and long endurance. The core of her S2C reactor is two-thirds the height of an S5W; her speed will not match that of *Nautilus, Skate* or *Skipjack;* but the reactor is designed to set new standards of accessibility, speed of startup, and operational flexibility.

Skipjack is of course the first of the true submarines of the future—the first to be liberated from the traditional compromise hull shape used in the last 40 years in submarines that were really torpedo boats having the ability to submerge for a day at a time, but still prisoner of the surface.

Skipjack has proved a source of joy to the Navy in the five months she has been in operation ("Everyone who's been out on her comes back here chuckling to himself, happy as a clam," says a former nuclear sub skipper now in the Pentagon). Her speed is a closely-guarded secret, but a good guess would be in the range of 35–40 knots (40–46 mph) submerged; the Navy has said only that she has traveled faster and deeper than any submarine in history. On the surface, her after ballast tanks have to be partially flooded to hold up her bow, as her hull shape, designed for optimum performance underwater, seeks by itself to submerge. Underwater she handles as freely as an airplane in the air. She is so easily controlled that it's said the only problem is the danger that her crew may be lulled out of alertness, like a turnpike driver.

Her S5W reactor gives her a range of 90,000–100,000 miles at full power. Its operation is said to be such an advance on *Nautilus'* reactor as to be a different order of magnitude. Design of the reactor and its circuitry is greatly simplified, and reliability and maintainability improved. Although S5W is reported to be 30% bigger than *Nautilus'* reactor, the *Skipjack* reactor compartment occupies only 20 ft of the ship's length. The reactor vessel is about 15½-ft high, 7 ft o.d. Coolant flow, as in the *Savannah* merchant-ship reactor, makes three passes through the core. The two-pass boilers have cyclone separators so as to deliver dry steam (¼% or less moisture carryover). Each of the two coolant loops has three canned pumps (a seventh is carried below decks as a spare). The first set of pumps, delivered by a new supplier, caused three months' delay in *Skipjack's* completion when 4 of 6 froze during testing. They were replaced. Refinement of the reactor vessel design has included elimination of stud holes in the head: the head is simply seated in place atop the vessel, and a bolting ring placed above it is bolted to the vessel, fastening the head.

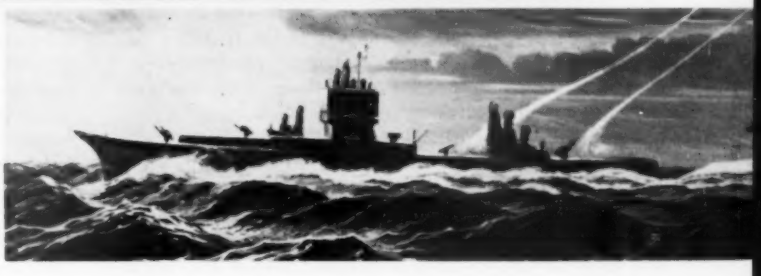
The ship's rod-control, rod-position and reactor protection system reduces from eight to five the number of racks needed, saving vital space by use of magnetic amplifiers (later models will reduce this further to three—by partial transistorization). To eliminate all possibility of spurious scram signals, coincidence circuitry is used, with everything wired in parallel. Scram signals are pressure drop, excess temperature, low coolant flow, or improper power-to-flow ratio. A "battle-short" switch, as is found on conventional Navy ships, overrides these safeties.

Skipjack's nuclear plant cost $12-million, 24% of the ship's $50-million total cost. Largest pieces of this include: core, about $2-million; a vessel $400,000; a pair of heat exchangers $500,000; a pressurizer $100,000; the main coolant pumps $840,000; the reactor plant controls $250,000.

Thresher is the lead ship of an improved-*Skipjack* class, now building at Portsmouth. Her S5W-2 reactor is designed for even greater core life, and is believed to resort to a lengthened meat section in the fuel elements to achieve this. She will go even faster than *Skipjack*, go deeper, have quieter machinery and improved sonar with listening range expanded fivefold, and will be the first submarine fitted to fire Subroc.* *Thresher* comes into operation in January 1961; she is the prototype for twelve subsequent SSN's (all except *Tullibee*).

George Washington is the first of the highly-touted FBM subs. These, often called the capital ships of the

* Subroc, "the torpedo with a Ph.D.," will be fired from a regular torpedo tube, swim to the surface, take off into the air as a missile, soar 40–50 miles to a point above its target, an enemy sub; plunge back into the sea, listen for its prey on its own sonar, latch on and close in, and destroy the target with its thermonuclear warhead.



USS LONG BEACH, world's first nuclear warship, as she will look upon completion and as she looked July 14, day of her launching, when she left her building basin for first time

future, are essentially mobile, underwater launching pads for 16 Polaris missiles. They will also be armed with torpedoes and extra sonar, so they will have an added capability as anti-sub craft, but their primary mission is as a deterrent force. In order to remain on station for the maximum time, these FBM subs will have two complete crews ("blue" and "gold") alternating every three months at sea. They will also be the first subs to be equipped with chemical oxygen generators in addition to air "scrubbers" and O_2 tanks used heretofore. Because of their incredibly complicated gear—the Polaris launchers, a target computer for each one, inertial navigation equipment to fix precisely the point of launching, etc.—each FBM sub will cost $100-million, double the price of a *Skipjack*, plus $50-million for a shipload of 16 Polarises. Nuclearly, however, they are just so many more *Skipjack* S5W installations. Interestingly, although the FBM sub has just twice the displacement of a *Skipjack*, she will lose only 2½–5 knots from the latter's speed using the same powerplant. This is because only 3 ft are added to her beam while most of the added size is in length—and adding length is favorable for speed. Thus these ships with their elongated *Skipjack* teardrop shape, modified only by a hump aft to accommodate the launching tubes, will still be considerably faster than *Nautilus*. *George Washington*, the lead ship, is scheduled to give Polaris its final tests next summer or fall.

Ethan Allen is the first of an improved *George Washington* class already under construction. She will run deeper than *George Washington*, and is expected to have the same kind of improvements that *Thresher* has over *Skipjack;* the faster, longer-lived S5W, quieter machinery, etc. She is also likely to be the world's biggest sub—the first to surpass *Triton*.

Surface Ships

Long Beach, the Navy's first nuclear surface ship, was launched in July and is scheduled to begin her sea trials next fall, prior to completion of her armament; she is to join the fleet in Spring 1961. She has two C1W reactors of 35,000 horsepower (26 Mw), each driving one propeller shaft. A key disposition for the ship will be a "propulsion plant enclosed operating station" for each reactor: a glass-enclosed, isolated control booth from which the reactor and its associated turbine's throttle can be remotely operated. In case of emergency, "crossover operation" will be possible: running one turbine from the other reactor, or even both engine rooms from one reactor. Each reactor will have four coolant loops, and although normally using all four in service, will be able to make full power with only three operating. The ship will be capable of about 30 knots.

Enterprise is the world's biggest warship, and quite possibly the biggest ship in history. This stupendous vessel, displacing 86,000 tons, will be driven by eight reactors feeding 32 heat exchangers; each reactor develops 35,000 shp for a total of 280,000. Like *Long Beach's* essentially-identical reactors, these are designed to run normally with all four loops, but to be able to make full power with only three. Both are expected to run five years on their first charge. The reactor core is so complex it takes 18 weeks just for assembly of the completed parts. *Enterprise* is built to make 33–35 knots, the same as the conventional *Forrestal* class of carrier. To meet her July 1960 launching date an unprecedented 1,000 machinists, electricians, pipe fitters and other skilled trades are working in the propulsion compartments alone, not counting several thousand shipwrights and welders on other parts of the ship. As of two months ago, four reactor vessels were in place and three more compartments had all other major associated components installed. The magnitude of the effort required to test components, systems and subsystems in eight plants and to keep everything in phase is also unprecedented.

Some savings in shielding weight were made possible by placing two reactors in each reactor compartment, and then placing the latter so that one corner of each abuts against that of another. For these nuclear surface ships, the propulsion plant is laid out by the builder and approved by Naval Reactors Branch but all the rest of the ship is designed—following Bureau of Ships specifications—by the builder yard: Bethlehem Steel's Quincy, Mass., yard for *Long Beach* and *Bainbridge*, Newport News Shipbuilding and Dry Dock Co. for *Enterprise*. In the case of submarines, the design is established by the yard building the lead ship: Electric Boat for all seven types other than *Halibut* which was the work of Mare Island Naval Shipyard.

Long Beach and *Enterprise* share in common—and have been benefiting jointly from—the A1W land-based prototype at the Idaho reactor testing station. This $35-million facility is a full-scale operating prototype of *Enterprise's* No. 3 machinery plant: two reactors and a turbine driving a slow-speed generator. Two full-scale reactors were felt necessary because the dynamics and control characteristics of two reactors connected to a single shaft were an unexplored area. Advantage was taken of the situation to develop two different core designs and to try out variants in nuclear components—for example, one of the reactors has all structural parts in contact with primary water made of carbon steel instead of 304 or 347 stainless, to test the feasibility of using this less expensive but more corrosible material.

Enterprise project leaders report that they are learning things every day from A1W test operations. These result in minor but essential design improvements as work progresses, but no major changes are contemplated.

Bainbridge at 7,900 tons is the smallest surface ship that can take nuclear power at today's state of the art. Her D2G reactors are a development of *Triton's* S4G pair. The ability to nuclearize the smaller ships—destroyers and destroyer escorts—may not come for another 5–7 years, BuShips Chief Admiral James told NUCLEONICS.

Nuclear Sea Experience

This, then, is "Rickover's Navy." How has it stood up so far in service?

Submarine officers all agree that most of what troubles they have had have been with conventional components. "The most trouble-free systems we have on board are the reactor systems," *Nautilus* ex-skipper Anderson says; "those that give us the most trouble are the 'tried and true' items like air conditioning and pumps. The reactor has given us no maintenance problems—most of the maintenance men's work has been on conventional stuff."

It may be that within the possibilities for improvement here there lurks an irreducible minimum, for it is part of the nature of high-speed rotating machinery to wear out, and certainly the A-subs have worked their rotating machinery far harder than any submarine parts have ever been worked. The percentage of high-power operation has not only been much greater than that of any conventional ship, but also much greater than the A-subs' designers anticipated.

As to details of nuclear performance, the Navy throws up the clammy veil of classification about any incidents of reactor failure that may or may not have occurred; it will say only that "no nuclear submarine has ever failed to meet an operational commitment because of failure of its propulsion machinery." Rear Admiral A. G. Mumma, until recently BuShips chief, told NUCLEONICS, "*Nautilus* has had occasional breakdowns—you can't expect any serious chunk of machinery to go without derangement for indefinite periods—but there have been no serious ones."

One of the many unlooked-for beneficial side effects of the unprecedented hand-picking and intensive training of A-sub crews has been a bonus in maintenance work. "It has paid off not only in the nuclear field," Cdr. Anderson says. "We've done repairs on nonnuclear items that would have stopped a normal crew. For example, we have welders of stainless steel aboard, who have made repairs and even built parts." One of the requirements set up for A-subs has been that a certain percentage of the crew must qualify as stainless welders. A sub is even supposed to be able to change a main coolant pump, installing the spare that each one carries, using only its own resources—but in all except the most dire emergencies it would be easier to return home on reduced power.

The lengths to which the Navy is going to try to build reliability into its A-subs is well shown by this declaration from Admiral Rickover: "We build something and we test it in every way we can. For example, we ran the first pumps as much as 10,000 hours before we actually installed them in the prototype. We rigged up equipment at Bettis. We rolled them 30° from side to side while they were running. There was pitch under all of these conditions too. We tested them in a live submarine under depth-charge conditions. Congress permitted us to use an old submarine, and we installed these pumps in the submarine. We exploded a 300-lb depth charge 30 yards away. The pumps kept on working. We tested a lot of stuff that way. That is how we learned."

Another Rickover experiment was to burst a fuel ele-

USS ENTERPRISE, Navy's first atomic carrier, as she will look on completion, and as she looked (in a photo taken especially for this report) on July 29

ment deliberately in the *Nautilus* Idaho prototype to see if it could continue operating (it could). He found it was also possible to live with 100 gal/hr of water leakage in the prototype. Actually, testimony from the operating submarines is that the "zero-leakage" primary loops have really had literally zero leakage.

Sub Tender, Nuclear

So far, one submarine tender—the U.S.S. *Fulton*, stationed at the New London, Conn., home base of the Submarine Atlantic Fleet—has been able to take care of all the A-subs. This mother-hen of submarines ("Rickover may be father of the atomic submarine, but we're the mother") has added a clean room, stainless-steel welding rods and qualified welders, oxygen candles and oxygen analyzers, greater amounts and varieties of dehydrated foods and of electronic spare parts, and such exotic (to the submarine service) items as G-M tubes, high-purity hydrogen peroxide, 100-mc graduated cylinders. *Fulton*, which normally carries over 100,000 items—$2½-million in stock—including 21,000 submarine spare parts, now also carries 500 lb of dry ice and flasks of liquid nitrogen, either of which is used to freeze the water on either side of a line that needs to be opened for maintenance on a component or piping. *Fulton* is now in Philadelphia Navy Yard for a 5-month overhaul to outfit her more fully to handle A-subs. Her clean room will be improved, and nucleonics shops, storage tanks for contaminated water and spent ion-exchange resins added.

The sub tender *Proteus* is undergoing a more thoroughgoing conversion to fit her out for supporting Polaris submarines particularly, and the 1960 budget contains $61-million for building a new sub tender especially designed to mother Polaris subs.

The Expended Core Facility in Idaho has so far received three seagoing spent cores. Perhaps appropriately for a facility most of whose work is with submarine parts, this unique plant does many of its operations under 30 ft of water. Designed by Bettis and built by Paul Hardeman Inc. and Arthur G. McKee & Co., ECF has a "built-in process flow" to handle the cores that come in with surface activity levels of several million roentgens/hour. The core is unloaded at one end of the water canal and is moved along to stations where it is remotely sawed and milled into smaller pieces and samples sheared, punched or stamped for study in a series of nine special-purpose hot-cells. Fuel not selected for testing goes to the chemical processing plant, nonfuel elements are salvaged, and nonsalvageable waste goes to the burial grounds. ECF cost $4.8-million, was completed this year.

Other Core Problems

Atom percent burnup is believed to be low thus far—below 1% [10,000 Mwd/ton]. An effort is being made to raise it to over 1.5%.

For the longer-lived cores, new long-lived burnable poisons are required. Dispersed boron will no longer do; under consideration are hafnium and various other rare earths, as well as lumped boron.

The Navy is also understood to be trying to reduce the number of control rods.

For all their tremendous advantages to the submarine skipper, A-subs also pose some special problems. Xenon is one. Cdr. Anderson explains: "During most of core life xenon poses no problem because the core physics is such that we can override maximum xenon. Toward the final part of core life, however, xenon does impose some operational restrictions, which are relatively minor as long as they are faced up to. This means avoidance of shutdown at an undesirable time."

Until now all naval cores are understood to be zircaloy-clad and fully enriched. But a PWR-like seed-and-blanket core for surface ships appears to be under development. "We are trying to use a minimum of enriched uranium in the large cores," Rickover says. "A reactor for a submarine must be as lightweight as we can get it. We must keep it small. That is the reason we use enriched uranium in our submarine reactors. We get away from that, to a great extent, on the large surface-ship reactors where more space is available. . . . We are using . . . . as much natural uranium as possible, which can be used in one of the cores we are designing now, either in the carrier or the cruiser."

Oxide appears to be out for naval use, partly because of its greater weight, partly because of its poorer shock-resistance qualities.

One of the arguments Rickover made before Congress in favor of nuclear propulsion for the newly-authorized carrier is that the incremental cost for nuclear power would be less than the $120-million previously used as yardstick. This is thanks to improved core designs and a BuShips study for a nuclear carrier using only four instead of eight reactors. A four-reactor carrier would have all the characteristics of *Enterprise* except for being about 1 knot slower. Its cores would be good for five years.

Natural Circulation

However the main forward-looking project at NRB these days is the NCR or Natural Circulation Reactor for which AEC has just obtained $18½-million. This is a project to do away with main coolant pumps, coolant check valves, pumps' generators and controls. Advantages: eliminating the coolant pumps would do away with the second noisiest item (after main reduction gears) on board a sub; there would be a net saving in weight even though the reactor and heat exchangers would have to be larger; the potential danger of a cold-water accident would be eliminated; and reliability and maintainability would gain by elimination of components and piping.

Bettis and KAPL have both been working on this concept, the former for a year and half. One will be chosen to design and build a full-scale prototype in Idaho, to be completed in 2–2½ years (and if the concept is successful, the first shipboard installation could be begun in 3–3½ years). The concept is creating new problems in reactor physics and kinetics, such as the fact that in the absence of forced circulation, flow patterns are strongly affected by the attitude of the ship under pitch-and-roll conditions, in turn affecting power output. This can be controlled, but at the expense of de-rating the core as some parts are operating hotter than they would if the reactor were truly vertical. To solve these and similar problems, the prototype reactor is to be mounted on pitch-and-roll gimbals.

BUILDING THE NUCLEAR NAVY—2

Industry Mass-Producing Reactors for Navy

MASS PRODUCTION of power reactors, a persistent dream of future utopia, is actually being carried out today. It has been achieved by the U. S. atomic industry, now building pressurized-water reactors to equip our nuclear navy on what is beginning to take on aspects of a production-line basis.

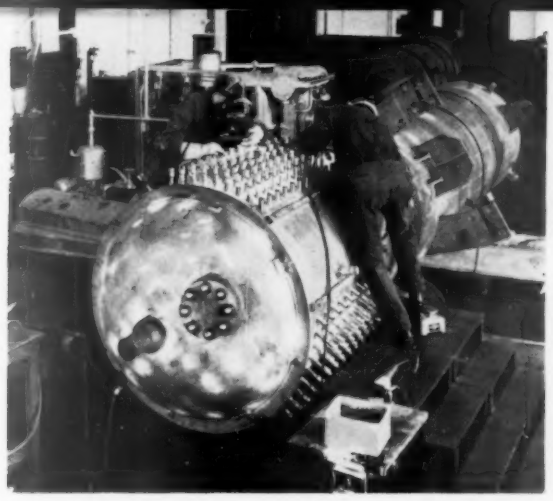
Standardization in reactor building, by the same token, has also arrived—thanks again to the nuclear navy's orders for 27 S5W and 12 C1W-A1W-A2W reactor propulsion plants. The outlook is for greater use of production-line techniques, and—consistent with introduction of improvements—increasing standardization.

The fact that beginning with the 1957 shipbuilding program all submarines (except *Tullibee*) use the S5W reactor has meant that the Navy has already begun to reap the benefit of savings from series production. For example, fabricators of core structural components—the myriad complicated, precision-machined stainless-steel parts that go into a reactor vessel along with the fuel elements—report that the cost of one set has already come down 40–45%: from $340,000 to $200,000 for S5W, from $1.2-million to $740,000 for A2W. Newport News Shipbuilding & Dry Dock says it has learned over the years that the savings to be made from duplication continue to grow till the 4th or 5th unit, where one "has reached maximum effective use of the knowhow required at all levels. Obviously, with eight reactors," a veteran naval architect there adds, "there are real savings to be made." Likewise, "there is considerable labor saving by building two subs at a time."

The Prime Contractors

Standardization has brought with it an unexpected phenomenon. The success of the S5W and C1W-A2W systems has won for their designer a virtual stranglehold on prime contracts with the result that today's nuclear navy has a very decided Westinghouse color. Of the first 36 A-ships, 33 (31 submarines, the carrier and cruiser) are powered by Pittsburgh reactors, with only one sub and the frigate left over for GE and one sub for Combustion Engineering. This has left Westinghouse's Bettis organization in the position of dispenser of subcontracts and all-around Grand Vizier of the navy program. To fulfill this role Westinghouse set up an organization early in 1956 with the deceptive title of Plant Apparatus Division, whose primary function is to act as purchasing agent, expediter, and inspector charged with getting all the propulsion equipment items to the shipyards on time. But PAD has another function—an engineering role, supplementing Bettis. Whereas the task of the 90 engineers in Rickover's headquarters organization—a part both of AEC where it is called the Naval Reactors Branch, and of the Navy where it is Code 1500—is to set program goals, direct, supervise and approve; and whereas the 1,300 scientists and engineers at Bettis carry out the development work and conceptually design the final prod-

NAVAL REACTORS FACILITY at AEC's Idaho testing station (left) showing (A) *Nautilus* prototype, S1W; (B) S1W cooling spray ponds; (C) administration building ;(D) A1W large ship prototype; (E) A1W cooling towers; (F) Expended Core Facility; (G) active waste disposal; (H) switchyard. BETTIS LABORATORY main site (right) at former Bettis airfield southeast of Pittsburgh



CRUISER PRESSURIZER having its calrod heaters set in place in Dunkirk, N. Y., shops of Alco Products. This is in a clean room such as is found in every major nuclear navy facility

A CLEAN ROOM pipe shop. This one is at Newport News Shipbuilding & Dry Dock Co. Note air-filtered work booths in rear, sealing of all pipe ends

uct,* there is still another engineering job to be done. No propulsion plant order is the same, not even duplicate orders; there are continual modifications and adaptations to be made to make different components from different suppliers compatible, or to take into account improvements or minor changes to accomplish compatibility with shipbuilding requirements. To do this—to draw up and coordinate specifications, PAD has 50–100 engineers among its 400 staff.

In the hope of obtaining a larger share in the Navy program, General Electric recently reorganized its atomic structure (NU, March '59, p. 19), meeting certain demands Rickover is believed to have made. GE's KAPL lab, just coming to grips with the problems of reactor miniaturization in the D1G prototype and *Bainbridge*, is also designing improved and longer-lived reload cores for *Triton*, and is evaluating several new reactor concepts including the Natural Circulation Reactor.

At Combustion's new $25-million Windsor, Conn., facility, the S1C prototype for *Tullibee* is about to go critical while a mile away the fuel-element plant's eighth Navy core is being completed. Combustion has also recently reorganized, with its naval section split off from the domain of nuclear Vice-president Walter Zinn.

The N-Navy Builders

Core fabricators are five in number: Babcock & Wilcox, Lynchburg, Va.; Combustion Engineering; M&C Nuclear (now a subsidiary of Texas Instruments Inc.), Attleboro, Mass.; Olin-Matheson, New Haven, Conn.; and Westinghouse's Atomic Fuel Dept., Cheswick, Pa. Of the many hard rows to be hoed in the naval program, they have one of the hardest. Failure of a new manufacturing process approved in advance in writing by NRB can suddenly cost a firm a million or two in wasted material, labor and time. (Exactly this has actually happened.) Yet competition remains keen.

Heavy components makers—pressure vessels, heat exchangers and pressurizers—find Babcock & Wilcox (Barberton, Ohio, plant), Combustion (Chattanooga, Tenn.) and Foster Wheeler (Mountaintop, Pa.) predominating. B&W, with the largest share of major S5W parts, has placed their fabrication on a production-line basis. With both Barberton and Lynchburg working for the Admiral, B&W is now doing a $15–20-million a year Navy business.

Alco Products, Dunkirk, N. Y., is moving in with the leaders in heat exchangers and pressurizers. Westinghouse-Cheswick and GE are carrying the load on main coolant pumps, and there are specialists in most of the numberless other parts of a primary system.

One of the unusual specialties spawned by the Navy program is making core structural components. These are the odd-shaped but incredibly precise stainless steel parts that go into a core barrel with the fuel elements: manifolds and flow baffles, grid plates, tie-rod guides, module tubes, shear locks, etc., made to a tolerance of 0.0002 in. by precision machine shops.

For that matter, an S5W vessel itself is not the two pieces—vessel and head, plus studs—that one might think. It is a fantastically complex arrangement of 474 super-precision-tooled parts—thermal shields, spider skirts, backing rings, alignment lugs, etc.

Shipyards are seven. Two navy yards—Portsmouth, N. H. (actually in Kittery, Maine), and Mare Island on northern San Francisco Bay—make subs. Electric Boat division of General Dynamics is the pioneer and "old-timer," having been in the field seven years; it is the builder not only of *Nautilus* and *Seawolf* but also of the lead-ship of every new A-sub class, except *Halibut;* EB is now on its eleventh U^{235}-boat. Bethlehem Steel's Quincy, Mass., yard specializes in surface ships—*Long Beach* and *Bainbridge*. Newport News Shipbuilding & Dry Dock Co., the country's leading carrier builder, has *Enterprise*, but it has also entered the A-sub field to stay, with four. New York Shipbuilding Co., Camden, N. J., as builder of *Savannah*, is the only yard to enter the nuclear navy program with previous A-ship experience. Ingalls, at Pascagoula, Miss., rounds out the nation's A-sub building capacity on our third coast.

The shipyards are not just consumers of nuclear products—they are very much in the nuclear business. The builder of a lead ship must make the over-all heat balances, design piping and circuitry, as well as design the shielding. Beth-Quincy and Newport News, to name only two, have carried out major research programs on lead and the special problems of welding vertical lead seams on bulkheads. Welding 3–5 *inches* a day is good,

* KAPL has about 500 engineers and scientists, Combustion 200, 150–200 in BuShips, and 1,000 in the subcontractors' labs and shops, for a total around 3,300.

and *Long Beach* has 4 vertical seams 30-35-ft high, plus horizontal seams, in each reactor-compartment bulkhead.

Tooling Up for A-Ships

The extent to which any one of these companies—core or primary hardware makers or shipyards—has had to install special facilities for nuclear work is awesome. Each of the principal plants mentioned above—the five core factories, seven shipyards and three major component factories—represents an investment of at least $3-million, perhaps more. The "clean room" for pipe or component assembly under close to surgical conditions of cleanliness has become a trade-mark of plants working to build Rickover's Navy (*see photo*). Newport News also has a clean core building designed to handle all the components for three cores simultaneously, for inspection and assembly. Among other special facilities this work demands are cobalt-60 gammagraph and X-ray equipment ("We used to X-ray one inch per mile of weld. Now we X-ray the mile"); demineralized water equipment, 2,500-ton steel bending press ($440,000), 3,000-ton hobbing presses, 184-in. vertical boring mills ($300,000), horizontal boring mills ($500,000), gage rooms with optical equipment for alignment of pieces (one optical transit alone $22,000), magnaflux, dye-penetrant and ultrasonic test equipment.

The need for super-cleanliness was never so clearly brought out as in The Great Smidgin Hunt of 1958 at KAPL, when the entire Navy fuel element business was practically shut down while frantic nuclear engineers sought the cause of an activity level in the S3G coolant water higher than expected due to trace amounts of iodine—although still well below maximum permissible levels. It eventually was traced back to the fact that some of the fuel elements, although acceptably clean and sound on inspection, had once been tested in an autoclave that earlier had been used to test bare uranium.

Quality Control: Panacea or Scourge?

The one paramount thing that is different about working for the nuclear navy, all industry agrees, is quality control.

Involved is a revolution in attitudes. "Quality control is king," says general manager Henry Schneider of Freitag Mfg. Co., a leading maker of core-structural parts. "They don't answer to production—they tell me what to do. They answer to nobody."

Machinists who used to machine to a drawing as best they could and disregard the details now are exhorted to "pinch the inch." But exhortation is not all: a complete history or "traveler" is attached to every piece of metal, every joint; and every worker's name is recorded for every operation. Every test, every inspection is recorded. Thus every failure can be traced back. ("One file drawer used to hold the papers for everything in the shop," says Alco's quality control chief. "Now the records for any one nuclear component fills a drawer by itself.")

The quality control staffs have expanded greatly—300% in the last two years, reports one firm; up to 20% of total force, reports another. Newport News has added

Rickover—How Industry Sees the Navy Program's Boss——

In a dingy two-story building known as "N Building" tightly sandwiched between the Main Navy building and the Reflecting Pool in Washington, Vice Admiral Hyman George Rickover has his headquarters. From an upstairs office in this, one of the more depressing of Washington's decades-old "temporary" government structures, he runs a multi-billion dollar empire encompassing a fair-sized segment of U. S. industry, with the peremptory despotism of an ancient Persian satrap.

The phenomenon named Hyman Rickover has parlayed single-minded determination and a savagely sharp tongue into a brilliant career, having become one of the greatest contributors ever to U. S. naval power. The story has frequently been told how in his early days of adversity he beat down opposition with his now-famous two-hat system: as Chief of the Naval Reactors Branch at AEC and Assistant Chief for Nuclear Propulsion of the Bureau of Ships at the Navy, he was able to write letters to himself, answer them, and thus cut red tape by being in a position to commit both organizations.

But there is also another whip-saw technique he has perfected, to maintain and extend his authority outside the Navy-AEC sphere. Because he testified before Congress with brutal frankness (and didn't hesitate to talk back saucily or acidly to Congressmen who were unenlightened, by his lights) he early won Congress' admiration and active, even aggressive, support. With this support behind him, he was able to bully industry into getting things done for him, on his terms. Because he did that, Congress admired him the more as a man who "produced." And so the circle—or rather spiral—was complete, and Rickover rode it to his present impregnable position. "A straight line is the shortest distance between two points even if it bisects six admirals," Rickover once remarked when he was a captain; today he will still not hesitate to bisect any six people, of whatever rank or station.

Like many very strong personalities, Rickover inspires either veneration or detestation in those who come in contact with him—little in between. One is apt to find two views of him among those who work for or with him: one of wholehearted, or grudging, admiration, another that is unprintable. The former point to his ruthless tenacity in pursuit of ever-higher quality and ever-shorter delivery

ADMIRAL RICKOVER explains a reactor to Senators Anderson (left) and Jackson

six quality-control engineers, 60 quality-control inspectors. Inspection time runs 20–30% higher for nuclear navy than for commercial work.

Needless to say, each company starting out had its headaches before it ascended the learning curve. Rejection rate on pieces delivered to one shipyard was said to run 75% for a while.

The anguish rate is still high for fabricators of parts. Most machine-parts and machinery makers feel the tolerances required are higher than they need be. Sample comments:

- "These reactors are designed by eggheads, not practical people. You'll see tolerances loosen up as reactors become more widespread."
- "The Navy talks millionths of an inch. This only exists in the mind." (It's explained that unlike carbon steel, stainless is a rubbery substance that doesn't hold dimensions precisely—no help on strict tolerances.)
- "Somebody's got to simmer down on these quality requirements to which we build ships. . . . We say a weld is good enough, but we can't take a position that anything less than perfection is good enough, and we can't *prove* it's perfect. So we get hit over the head—they tell us we're turning out sleazy work."

On the other hand many attribute the outstanding performance and reliability records that *Nautilus* and her sisters have maintained to the results of quality control.

What about profits? Many see them as a carrot dangled just out of reach by NRB. Rickover has proudly told Congress that "We are buying everything for the nuclear plants, not only for the submarines but for the carrier, from three different sources of supply on a 100% lump-sum competitive basis."

Many feel that Rickover is trying to convert the program from cost-plus to fixed-price too early, before companies can stand it (*see below*). "Rickover is trying to horse us into a fixed-price contract," says one industrialist. "We are agreeable if the price is high enough—but with a ship only half designed, how can you?"

The core makers complain they have tooled up for a higher output level than has materialized. B&W needs eight S5W core jobs a year to keep Lynchburg up to capability; Combustion 8, M&C Nuclear 8, Olin 12, Cheswick 8, for a total of 44. But Rickover—who a year ago was promising his core makers 12 cores a year each—now is reported as saying he will be buying 20 S5W equivalents a year, total (an A2W equals about 1½–2 S5Ws).

On the other side of the fence is Electric Boat, so busy it is adding new shipways. Manager Shugg says, "At this shipyard we've made a reasonable return. But we've had to plow most of that back in. To keep going at this thing you have to put in sizeable expenditures each year on new facilities." Westinghouse also is said to have stopped losing money on nuclear navy business. There are optimists who would interpret the success of these two firms, longest in the business, as a sign that success awaits those who stay the course.

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times, to his brilliant engineering intuition. They are those who feel that the ends justify the means—that the only reason America has Nautilus and her sisterships as a force-in-being today is because Rickover so doggedly harassed and bulldozed industry into accomplishments that inertia alone would otherwise have retarded or frustrated, and thus that the toes Rickover stepped on were the price—a small price—paid for our advance in nuclear naval propulsion.

The other group (and if truth must be told, by far the larger one) feels that however great Rickover's undisputed contributions to U. S. engineering progress and military security, his terrorizing of his associates and of industry has been unnecessarily great. Among the complaints cited, some of the more frequent are:

- Approval or establishment of a system in which Rickover's lieutenants and company-liaison officers, behaving like so many little Rickovers, are in the position of having to blacken the companies' actions, attitudes or production records in order to justify themselves with Rickover and hold their own jobs.
- Constant forcing of all who work for him to justify themselves at every step. "You can be the best machinist in the world, but that's no longer enough—you must be articulate enough to be able to explain persuasively what you propose to do on a job, and how you're going to do it." (Ironically, Rickover is said to have observed in his youth, "The trouble with this country is that most of the bright young men are inhibited as a result of constantly having to justify themselves.")
- Interference with companies' personnel down to lowest levels. (" 'Does that man know how to run that machine?' 'He's been operating it for 30 years.' 'I don't know—he looks sloppy. His overalls are dirty.' Result: the unfortunate, though an expert, is taken off Navy work. We don't mind Rickover working over top management, but his hectoring of rank-and-file workers is really brutal.")
- Playing one contractor company off against another. Use of expressed or implied threats of withdrawing Navy business—after a firm has invested millions in equipment—to dictate terms and details.
- Forcing companies into huge investments to tool up for a given level of production, and then not having the work to keep them busy. (In all justice to Rickover, this may often be the fault of the Budget Bureau.)
- Insistence upon fantastic dimensional tolerances such as had never been heard of before in machining work, which drives costs up equally fantastically—and often has to be absorbed by the company. Many feel reactor plants would work equally well with tolerances one order of magnitude more realistic—but this could only be shown by experimentation, and Rickover is extremely conservative in engineering, deciding all questions on the side of conservatism.
- Imposition—too soon, many feel—of a fixed-price contract system on an industry that had not been able to make any money even on cost-plus contracts because the Navy disallowed costs of installing facilities and training workers, and because waste ran so high during each firm's learning-period for the new quality-control systems.
- Demands that companies working for him do so exclusively, and agree to take on no other atomic work, for certain periods or in certain facilities.

On the other side of at least one of these points, it should be said in fairness that some companies now admit that they would have been saving money for years had they applied quality-control methods to conventional work.

As a vice admiral, Rickover today outranks his Navy superior, the Chief of the Bureau of Ships—a rear admiral's billet. Now 59, he can look forward to at least three more years of active duty before reaching retirement age for vice admirals at 62, and can then be retained on active duty "at the pleasure of the President" until 64.

Pneumatic Tubes Speed Activation Analysis

By getting samples from the reactor to the counter in seconds one can use short-half-life neutron-activation products and make complete, sensitive analyses in half an hour

By W. WAYNE MEINKE, *University of Michigan, Ann Arbor, Michigan*

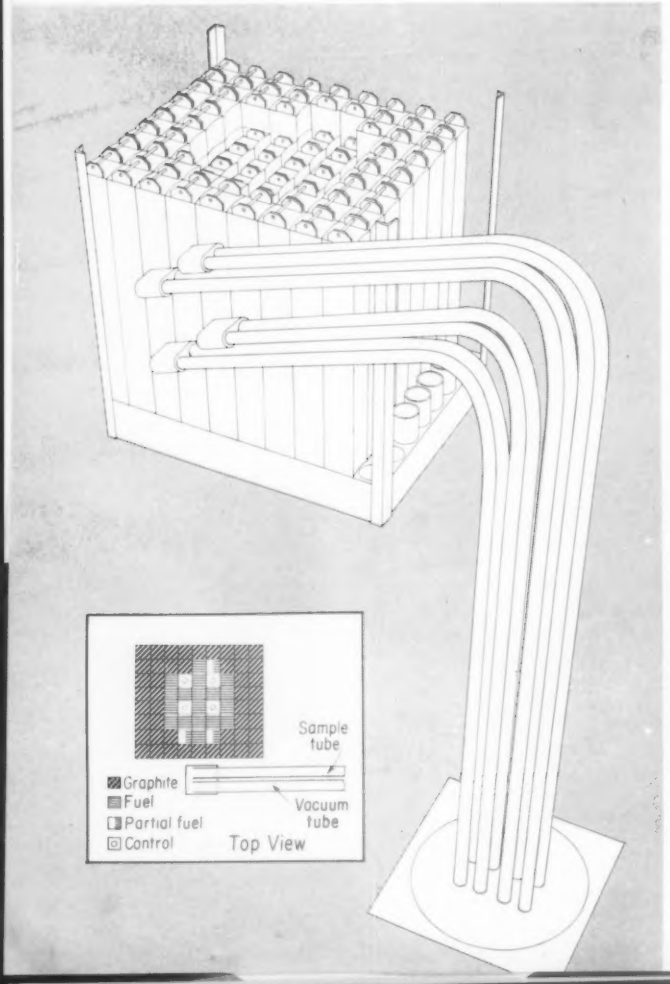

FIG. 1. VACUUM-OPERATED TUBES carry samples from hoods to positions shown beside reactor core. After irradiation, sample returns to hood for any chemical processing that is necessary before going to counter

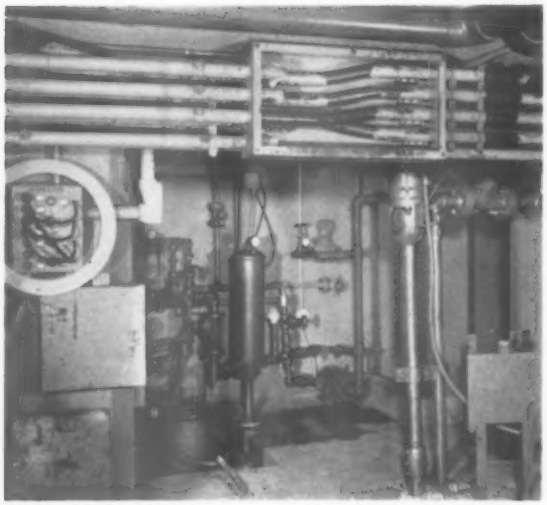

FIG. 2. INTERCHANGE, shown at top with cover removed, enables connection of any of six hoods with any of four exposure positions

ACTIVATION ANALYSIS (*1–4*) can be very time-consuming if samples are irradiated in a reactor for days or weeks and the long-life radioisotopes are measured. But pneumatic-tube facilities enable us to use nuclides with half-lives of minutes or even seconds. Analyses on all types of samples can be completed in periods of about half an hour rather than days. This opens many possibilities for routine application in industry.

A plot of cross sections against daughter half-life (*5*) or of activation-analysis sensitivity against half-life (*6*) shows that certain elements such as rhodium, silver, vanadium, aluminum, copper, niobium, and cobalt have high probabilities for activation of products that have half-lives of 10 min or less. Our group has studied several of these elements with considerable success. Detailed discussions will be published in the future.

Facilities

A set of fast pneumatic tubes carries samples to the side of the reactor. The exposure is timed automatically, and then the sample returns to one of several hoods. At the hood chemical operations can be performed, and then a second set of tubes carries the sample to our counting cave. Several types of detectors are available at the cave. Their pulses are fed to a pulse-height analyzer for rapid counting.

Pneumatic tubes. The rabbit tubes* between reactor and hoods come out of the floor of the pool to a position alongside the west face of the reactor next to the graphite reflector rods, as shown in Fig. 1. The system has four exposure positions at the reactor core, but there are six possible sending stations, four in hoods in an adjoining building (*7*) and two in the reactor building. Figure 2 shows the interchange system in the basement of the reactor building which makes it possible to connect any sending station with any reactor position.

FIG. 3. BUNNY RABBIT carries sample in a second pneumatic system from hood to counter. Here student inserts sample for trip to counter. Terminal of hood-to-reactor tube is visible on left wall of hood

We used to run with our samples some 90 ft down the hall to our detector system. Installation of our little "bunny rabbit" system has remedied this. Figure 3 shows a student inserting a sample into the bunny system after removing it from the rabbit tube, which is visible on the left wall of the hood.

The bunny tubes are made of ½-in.-i.d. aluminum pipe that is used in aircraft fuel lines and is readily available. Straight runs are made of hard pipe, and bends of softer material. The system is completely enclosed and powered by a vacuum-cleaner motor. Samples go from the reactor to the detector in 5 sec plus transfer and chemistry time. Thus we can work with half-lives down to the 11 sec of F^{20}.

Irradiation times from a few seconds to 20 min are controlled automatically by a timer mounted on the outside of the hood. The controls can also be operated manually.

Operating the system by vacuum rather than compressed air minimizes the possibility of contaminating the receiving station with radioactive dust from the tubes. This pneumatic-tube system has operated routinely during the past year and a half for over two thousand irradiations with few problems.

Rabbits. We have tried several types of rabbits in the larger tubes, but our preference now is for polyethylene rabbits, which are working very well. As shown in Fig. 4, rabbits are machined from plastic rod and gasketed with felt. A press-fit top is tight enough to prevent opening in the tube; yet it permits quick and easy uncorking. We have also experimented with some breech-type threads that open with a half twist. They appear to be just as good as the press fit and ensure that the rabbits do not come apart.

The bunny rabbits for the smaller tubes are polyethylene test tubes, 12 mm in diameter. We cut them to about 1½ in. and close them with corks.

When the rabbits are used only for short irradiations (5 min maximum), little long-lived activity is induced in them. The surface doses from nylon and polyethylene rabbits irradiated at 1 Mw and measured 3 sec after the end of irradiation are shown in Table 1 as a function of irradiation time. Most of the induced activity is in trace amounts of aluminum that remain after processing. Longer-lived components show traces of manganese and several other elements. About two thirds of the gross activity appears to be associated with the felt rather than plastic.

FIG. 4. PLASTIC RABBITS are made of nylon or polyethylene rod and gasketed with felt. Top has press fit or half-turn threads for quick opening

Since it requires only a few seconds to snap open a rabbit by hand, the dose to the hands for short irradiations is very small. Of course a large, hot sample in the rabbit could invalidate this premise and require remote-handling precautions. Finger-tab readings for most of our current work with short-lived nuclides, however, indicate that only a small dose is received at the hands from this type of manipulation. Thirty mr is a maximum for a week, which may include 10–20 irradiations. Most exposures are considerably less than this maximum. (*Cont.*)

* Airmatic Systems Corp., 441 Market Street, Saddle Brook, Rochelle Park, N. J.

TABLE 1—Dose Rates from Rabbits

Irradiation time	*Surface dose rates* (mr/hr)*	
	Polyethy ene	*Nylon*
15 sec	35	30
1 min	140	100
2.5 min	260	200
5 min	310	250

* Measurements were made 3 sec after irradiation at 1 Mw.

Much of our experience with nylon rabbits occurred while our reactor was operating at a power of 100 kw. With the reactor at 1 Mw we had trouble with these rabbits. Nylon screws holding the felt bumpers on both ends tend to become brittle and loosen. One rabbit that had been irradiated for a total of many hours broke into pieces as it emerged from the tube. These problems have necessitated careful periodic inspection and testing of all rabbits.

We expect our polyethylene rabbits to take at least several times the dose that the nylon ones can. We are still using the nylon rabbits that we have on hand, but we will eventually go over entirely to the polyethylene ones.

Reactor. Michigan's Ford Nuclear Reactor is a swimming-pool type with a maximum power of 1 Mw and a corresponding maximum thermal flux of $\sim 10^{13}$ n/cm²/sec. From April, 1958, it operated routinely at 100 kw, and since last September it has been operating at 1 Mw. Table 2 shows thermal-flux data measured at our four exposure positions with gold foils at a power of 100 kw. With 1-Mw operation the fluxes are about ten times as great.

In addition we made an absolute-activity measurement for tube 2. Dilute solutions of gold and manganese approximately equivalent to 20-μg/cm² foil were irradiated in small square polyethylene envelopes. Activity values of bare and 20-mil-cadmium-covered samples were used to calculate the cadmium ratios for the four pneumatic tubes shown in Table 2.

A variation of flux of $\sim 8\%$ along the length of the rabbit and of $\sim 30\%$ from side to side was observed. Experiments conducted both at 5 watts and at 100 kw gave similar results. Four rows of three small gold foils were taped

FIG. 5. COUNTING POSITION has bunny tube with solenoid-actuated stop above 3- × 3-in. NaI crystal. Arrival of sample automatically starts 100-channel analyzer

at 90-deg intervals on the outside of the rabbit, and their specific activities were compared. Self-shielding contributions of sample and rabbit are negligible. The results are not inconsistent with the geometry of the pneumatic-tube position and the attenuation of the neutron flux in the water moderator. The data obtained indicate that care must be exercised in the positioning of samples and monitor foils inside the rabbit to ensure reproducibility from run to run.

The fast-neutron spectrum in the pneumatic tubes has been determined as a basis for the estimation of possible n,p interference in activation analysis and for the possible production of carrier-free isotopes. The $Al^{27}(n,p)Mg^{27}$, $Mg^{24}(n,p)Na^{24}$ and $Al^{27}(n,\alpha)Na^{24}$ reactions [effective thresholds 5.3, 6.3, 8.6 Mev, respectively (*8*)] were used for these measurements. Experiments and calculation showed that the n,γ contribution from impurities created in the high-purity foils was below a detectable level.

Table 3 shows the shape of our fast spectrum. To obtain these data, magnesium and aluminum foils were enclosed in a 10-mil cadmium envelope and irradiated. After a 30-min decay (to eliminate 2.3-min Al^{28}) the 9.5-min Mg^{27} was measured absolutely with a 3- × 3-in. NaI(Tl) detector, our 100-channel analyzer and a set of efficiency curves (*9*). After a decay period of several hours the 15.0-hr Na^{24} was counted in a calibrated scintillation well counter.

The ratios of Mg^{27} activity produced in the pneumatic tubes were close to the ratios obtained for the thermal flux. These ratios, combined with the absolute flux values measured in tube 2, are the basis for the values listed in Table 3. At the high neutron energies involved here, the spectrum shape is approximately that of the fission spectrum even in the presence of considerable moderator. As in Table 2, these values should be multiplied by ~ 10 for 1-Mw operation.

FIG. 6. ANALYZER operates on cycle as short as 10 sec, records spectrum in two digital memories, prints it, plots it or presents it on oscilloscope

Counting

After the rabbits are delivered to the hood, they can be subjected to rapid radiochemical processing or measured immediately in a variety of detectors. We have a Radiation Instrument Development Laboratory 100-channel pulse-height analyzer with dual memories connected to a 3- × 3-in. Harshaw NaI(Tl) crystal. This detector is housed in a 40- × 40- × 40-in. cubical cave extended out the side of the Phoenix Building below the ground level.

The concrete of the cave is lined with ½-in. lead shielding covered with 0.032-

TABLE 2—Thermal-Neutron Data at 100 kw

Tube	*Relative thermal-neutron activity*	*Thermal-neutron flux* (n/cm²/sec)*	*Cadmium ratio*	
			Foil†	*Solution‡*
1	0.91	1.8×10^{11}	15	10
2	0.73	1.40×10^{11} (Au*) / 1.47×10^{11} (Mn§)	15	10
3	0.48	9.5×10^{10}	15	10
4	1.00	2.0×10^{11}	15	10

* Based on σ_{th} of 98 for gold. † 1-mil gold foil. ‡ Solution equivalent to 20 μg/cm². § Based on σ_{th} of 13.2 barns for manganese.

TABLE 3—Fast-Neutron Data at 100 kw (10^8 n/cm²/sec)

Tube	*Relative flux*	$Al^{27}(n,p)Mg^{27}$ (*>5.3 Mev*)	$Mg^{24}(n,p)Na^{24}$ (*>6.3 Mev*)	$Al^{27}(n,\alpha)Na^{24}$ (*>8.6 Mev*)
1	0.84	6.9	4.0	0.80
2	0.74	6.1 ± 0.1*	3.5	0.71
3	0.50	4.1	2.4	0.48
4	1.00	8.3	4.7	0.96

* Error is standard deviation for 7 samples.

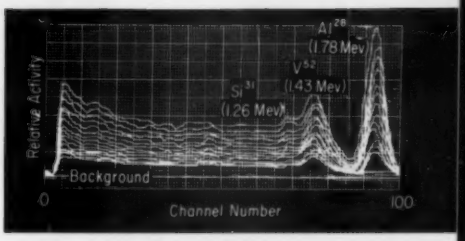

FIG. 7. COUNTING CURVES like this are automatically plotted by analyzer system. These show successive 30-sec counts of cracking catalyst

in. cadmium sheet, which in turn is covered with 0.005-in. copper sheet. The experience of Heath (*9*) seems to indicate that a cave of this size best reduces backscattering peaks.

The different linings reduce unwanted X-ray peaks; when lead is struck by energetic gamma rays, a lead X-ray is produced; cadmium absorbs the lead X-ray but in turn emits a cadmium X-ray which is absorbed by the copper. A 4-in. steel door closes the access hole to the cave.

In addition to the 3- × 3-in. gamma crystal we can use the following detectors with our analyzer: a 4-in.-diameter krypton-filled X-ray proportional counter (*10*), hollow plastic beta scintillation detectors (*11*) and a NaI scintillation well detector.

For counting, the sample is sucked into the cave and stopped by a solenoid-actuated bumper. Figure 5 shows the counting position with the 3- × 3-in. crystal beneath the bunny tube and the solenoid projecting upward. Arrival of the sample automatically starts the 100-channel analyzer. Energizing the solenoid allows the sample to continue through the pipe to a repository in our hot laboratory.

Alternatively, the sample can be placed in the Lucite sample holder by hand.

The dual memories of the analyzer can be used so that consecutive spectra can be recorded from short-lived nuclides without losing data through the 1-sec/channel deadtime associated with the printing cycle in an ordinary 100-channel analyzer. In our instrument one memory stores counts coming from the sample while the other is plotting out its spectrum. At a predetermined time—as short as 10 sec if 20 channels are adequate—the memories can be switched, and the second memory starts plotting out its data. This analyzer (Fig. 6) presents spectra data on an oscilloscope, prints numbers on tape or plots data automatically.

Figure 7 shows a typical set of counting curves. These are the gamma spectra of a cracking catalyst after a 1-min irradiation in a thermal-neutron flux of 7×10^{11} n/cm²/sec. The time interval from curve to curve is 30 sec.

Calibration

Power and flux calibrations of the reactor itself have no effect on our experiments. We put known standards with all our samples. Calibration curves made for these standards permit us to determine exactly the value of the amount of unknown.

In addition we always include a gold foil for general flux monitoring. We find that over a period of several months the total thermal flux can vary by as much as 20–30% with different core configurations. On the other hand, within a day or a group of days when the core configuration is not changed, our values for consecutive runs with the standards are reproducible within a few per cent.

Thus we do not worry about core loading or calibration. We ask the reactor operator for runs at the gross power level of 1 Mw and take care of small changes with our standards.

Men at Work

Our techniques have been applied successfully to several interesting problems. Schindewolf and Wahlgren have made complete analyses of 0.1-ppm amounts of rhodium and silver in rock-like samples in 10–15 min. They used 4.4-min Rh^{104} and 2.3-min Ag^{108}. By a similar procedure Fukai has used 3.8-min V^{52} to analyze for vanadium in ashes of marine biological samples. With the reactor at 1 Mw the lower limit for vanadium in the scintillation well counter is estimated at 0.002 μg. Brownlee has a 30-min analysis for part-per-million amounts of vanadium in oil which involves no ashing, concentration or chemical separation.

We have irradiated a cracking catalyst and find that the 1.78-Mev Al^{28} peak makes it difficult to measure the vanadium we are looking for. A rapid chemical separation following a peroxide fusion solves the difficulty.

Analysis for cobalt in vitamin pills and rat tissues uses 10.5-min Co^{60m} successfully. Similarly an attempt is being made to utilize 6.6-min Nb^{94m} in analyzing biological ashes. It has even been possible to study the character of 14.1 sec Pt^{199m}.

* * *

This work has received the generous support of both the Michigan Memorial Phoenix Project and the U. S. Atomic Energy Commission. Thanks are due to H. J. Gomberg, A. H. Emmons, C. E. Ricker and the staff of the Phoenix Project for arranging for reactor irradiations and coordinating the pneumatic-tube irradiations with the reactor schedule. The author is indebted to U. Schindewolf, R. Fukai, M. Wahlgren, D. Kaiser and J. Brownlee for the experimental work. The tireless efforts of R. Shideler and H. Nass to keep the 100-channel analyzer in top working condition and of R. Maddock in making many of the measurements are also appreciated. Also acknowledged are the assistance of L. J. Hartzler and the RIDL staff in custom building our 100-channel analyzer.

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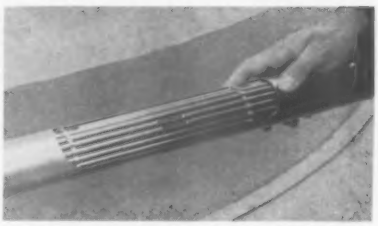
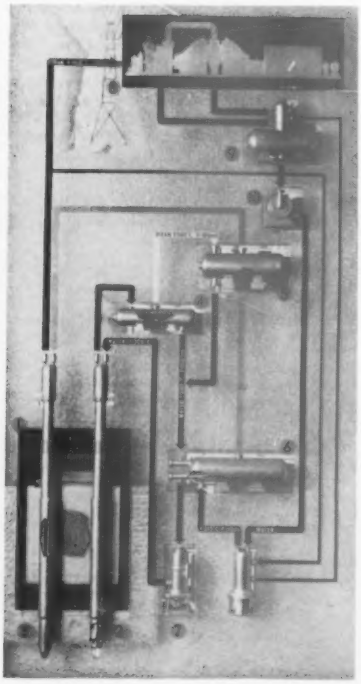


ATOMIC ICEBREAKER LENIN, most popular of many reactor models at show, here attracts early-morning crowd. In background is 18-ft full-scale model of one of Lenin's three reactors. LENIN FUEL ASSEMBLY (above) has casing and cladding cut away, exposing 5%-enriched UO_2 in two fuel pins to sight and touch of spectators

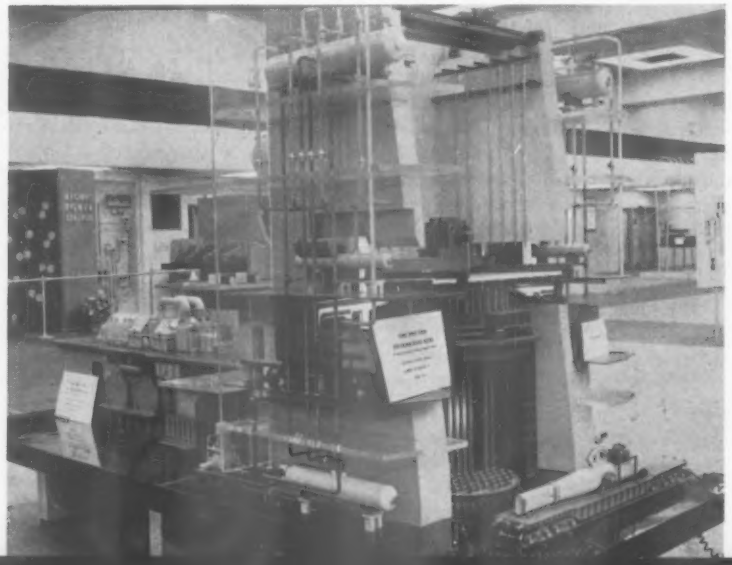
ATOMIC ENERGY was well represented in the massive Soviet exhibition of science, technology and culture, held in the New York Coliseum from June 30 to August 10. Over 10,000 sq. ft. were given over to displays on reactors, radiation applications, fusion and nuclear instrumentation. Staffed by nuclear experts, the entire exhibit was under the direction of Dr. Valery Kalinin who ran the Russian exhibit at the last Geneva conference (NU, Sept. '58, p. 25). There was much that had been displayed at Geneva, but there was also much that was new. In particular, there were two new reactor models, a masterful model of the Lenin (above), a quarter-scale model of the Alpha pinch experiment and many new radiation devices. Some of the most significant of these new displays are shown here.

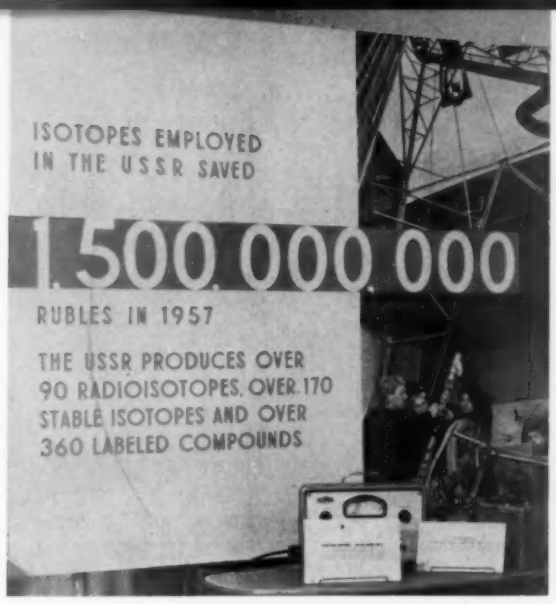
Hard information about the Russian program was hard to come by: for example the state of construction of three 50-Mw(e) reactors—fast breeder (BN-50), boiling-water, and sodium graphite—could not be determined. Nonetheless many members of the U. S. nuclear community took advantage of this opportunity to get to meet the Russians.

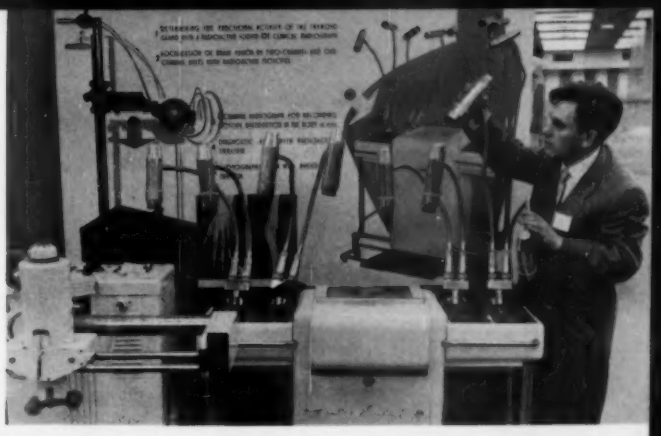
New York Exhibit Reflects



SUPERHEATED STEAM will be produced in 100-Mw(e) water-graphite reactor depicted by flow diagram (left) and 1/20-scale model (below). Reactor uses ss-clad 1.3%-enriched metal fuel assemblies similar to those that exceeded 23,000 Mwd/ton in first Soviet power reactor. Excellent steam conditions—930° F and 1,330 psi—result in plant efficiency of 35%. Vice-President Nixon recently toured site at Beloyarsk in Urals where two-reactor 200-Mw(e) [originally 400 Mw(e)] plant is being built

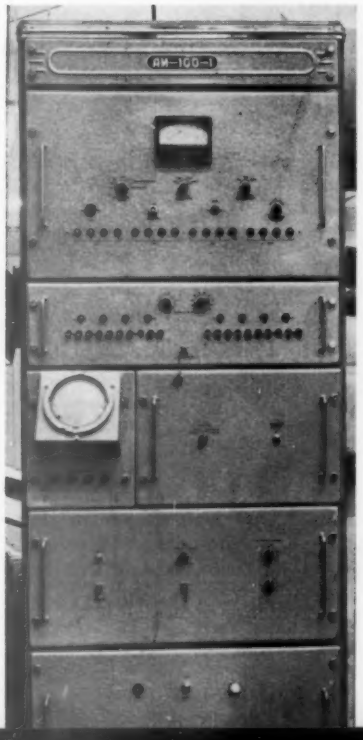


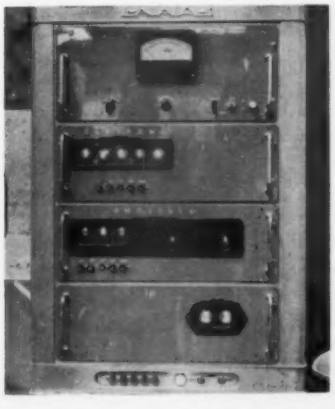


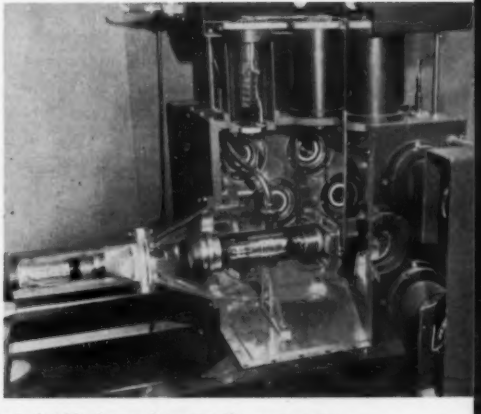


RED ISOTOPES save lots of rubles per year as indicated by poster above. At free exchange rate of 10 to 1 this is $150-million per year—between two well-known estimates for the U. S. EIGHT-ARMED scintillation counter (upper right) for radioactivity in the human body has removable shields for each of its eight scintillation crystals. Each channel has its separate readout. INTERESTED VISITORS Paul Aebersold (left), head of AEC's Office of Isotopes Development, and Bernard Manowitz (center), Brookhaven National Laboratory, listen to Leonid Petrov (pointing) and Vitali Kuleshov (far right). They found particular interest in radiation use for potato preservation, vulcanization and phenol production

Soviet Atomic Energy Progress







NUCLEAR INSTRUMENTATION included 100-channel magnetic-core-memory pulse-height analyzer (left); cathode-ray tube provides spectral display but output is read channel at a time using neon lights. SINGLE-CHANNEL ANALYZER (above) uses vacuum trochotron tubes for first two scaler stages, three gas-filled decade tubes thereafter. Numerical-indicator tubes show which of 25 fixed channels is being counted. COINCIDENCE EXPERIMENT on 10^{19}-yr double beta decay of Ca^{48} was conducted (above, right) in sea of liquid scintillator to anti-coincidence out cosmic rays. Sample is on slide at center of apparatus

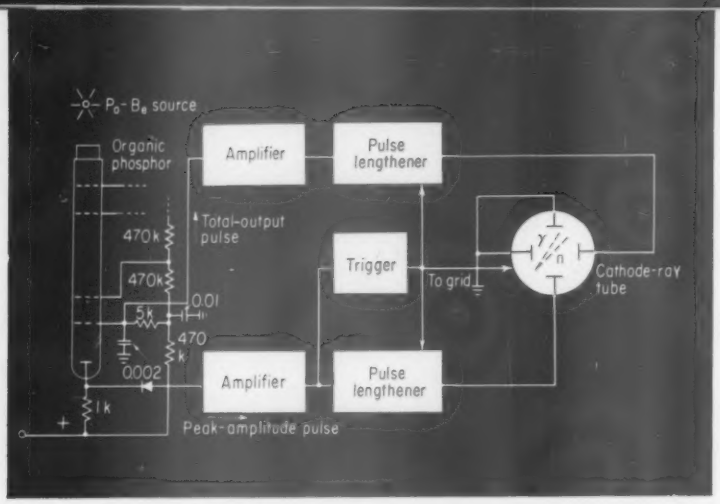


FIG. 1. PULSE-SHAPE DISCRIMINATOR gets total-output pulse from large-time-constant circuit at last dynode, peak-amplitude pulse from small-time-constant circuit at anode. Electrons and recoil protons produce two lines of spots

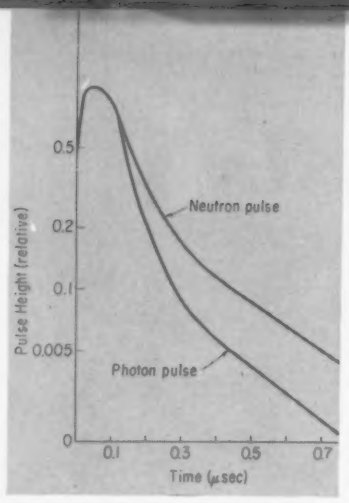


FIG. 2. NEUTRON AND PHOTON pulses in anthracene differ in slow and fast amplitudes

Pulse-Shape Discrimination

As the size of a scintillation tells the energy of a particle, the shape of the decay can tell the type of particle that initiated the pulse

By R. B. OWEN, *Atomic Energy Research Establishment, Harwell, Berkshire, England*

PULSE-SHAPE DISCRIMINATION can be used with scintillation counters to determine the nature of the particle causing a scintillation even as pulse-amplitude discrimination is used to determine the energy of the particle (*1*, *2*). The result is a useful extension of the information available from this kind of detector.

Scintillation pulses decay in a combination of exponentials of different time constants. Discrimination among types of particles is possible because amplitude ratios of fast and slow components of the relaxation are different for different types of particles.

Several types of circuits have been developed as pulse-shape discriminators. Some use small and large time constants to produce pulses corresponding to peak amplitude and total current from the photomultiplier. Others use space-charge limitation in the photomultiplier to distinguish a large-peak-amplitude scintillation from a small-peak-amplitude scintillation response.

As one might anticipate, different types of phosphors behave differently. This suggests that research in phosphors and liquid scintillators may show that neglected or unexplored materials are better for pulse-shape discrimination than materials now in use.

Pulse-Shape Recognition

The effects of differences in the shapes of fluorescence pulses can be demonstrated with the circuit of Fig. 1. Two pulses are taken from the photomultiplier. One, proportional to the total light output in the scintillation, is developed by the large-time-constant circuit of the last dynode. The second, which follows the profile of the current pulse through the multiplier, is obtained at the anode from a circuit having a small time constant. This second pulse is passed to an amplifier through a semiconductor diode (CG1C) so that the charge passed to the amplifier input depends chiefly on the peak amplitude, which occurs in the early stages of the scintillation.

After amplification the total-charge and peak-height pulses are lengthened (*3*) and applied to the two deflection systems of an oscilloscope while a brightening pulse is applied to its grid. Thus each scintillation produces a brightened spot on the cathode-ray tube. When only gamma photons excite the phosphor, brightened spots appear in a single line, but certain organic phosphors irradiated with gamma rays and neutrons from a Po-Be source produce spots in two distinct lines (*4*). It is at once apparent that the peak height of the pulses excited by fast electrons is larger than that of pulses excited by recoil protons.

Organic phosphors showing electron-proton pulse-shape discrimination include stilbene, quaterphenyl and anthracene. A notable exception is diphenyl acetylene (tolan), which does

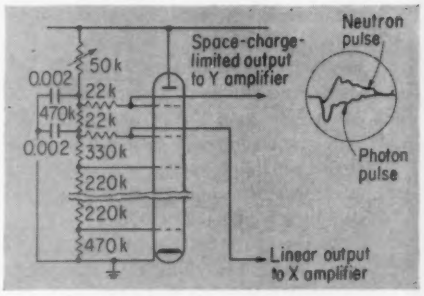


FIG. 3. SPACE-CHARGE LIMITING in this circuit causes negative pulse at last dynode from photon excitation, positive pulses from neutrons

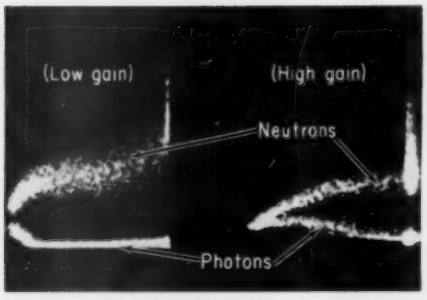


FIG. 4. NEUTRON-PHOTON DISCRIMINATION in stilbene with space-charge-limiting discrimination

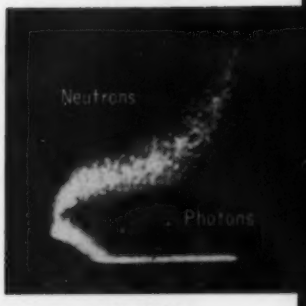


FIG. 5. DISCRIMINATION in liquid scintillator with POPOP

Identifies Particle Types

not show electron-proton differences. Scintillating liquids show electron-proton discrimination only if dissolved oxygen is removed. In this way good discrimination has been obtained with solutions of *p*-terphenyl (4 gm/l) + POPOP (0.04 gm/l) in toluene or xylene, and also PBD (8 gm/l) + POPOP (0.05 gm/l) in a solution of naphthalene (22%), xylene (31%) and trimethylborate (47%). Partial discrimination only has been obtained so far with plastic phosphors based on polystyrene and polyvinyl-toluene.

When inorganic scintillators such as CsI(Tl) or NaI(Tl) are tested with the arrangement shown in Fig. 1, the brightened spots again lie on two lines, but their positions indicate that peak height of the electron-excited pulses is less than that of the alpha-particle- or proton-excited pulses; that is, the effect is opposite to that observed with organic phosphors.

Fluorescence Decay

Shapes of scintillation pulses from organic phosphors can be observed directly by photographing them on a fast oscilloscope. When precautions are taken to ensure linearity of response in the photomultiplier, decay of fast components of the phosphor (typically 6 mμsec in the case of stilbene) is unaffected by the nature of the exciting particle. This agrees with other findings (*5*). However, previously reported slow components (*6*) are approximately twice as intense under proton excitation as under electron excitation (relative to fast components) (*7*).

The exact shape of this long-lived component is uncertain at present. However, if one interprets in terms of a series of exponential decays, the fastest component that shows different intensities for proton and electron excitation has a time constant of ~0.35 μsec for the crystalline organic phosphors anthracene, stilbene and quaterphenyl and 0.2 μsec for the liquid phosphors. Other long-lived components have time constants up to 10 μsec in the case of crystalline solids and 2 μsec in oxygen-free liquid scintillators. These components also are about twice as intense under proton as under electron excitation. Typical of pulse shapes are those in anthracene shown in Fig. 2.

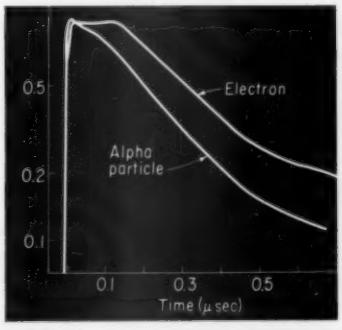


FIG. 6. INORGANIC PHOSPHOR has three-part pulse, resulting in flat top for electrons, sharp peak for alpha particles

A possible explanation of this behavior is that the fast component of phosphor decay is due to the radiative emission of molecules, excited directly by passage of the charged particle, while the slow components are due to excitation that results from recombination of ionized molecules and electrons. Thus the presence of electron-capturing impurities such as oxygen in liquid scintillators would reduce the intensity of slow components and destroy discrimination—which is observed.

Applications

Since chiefly the slow components of scintillation decay are affected by the nature of the excitation, particle identification is possible with relatively slow photomultipliers. Good discrimination between electrons and recoil protons in liquid phosphors is obtained with photomultipliers of up to 5-in. diameter (EMI 9530) although pulses from light distributed over the whole photocathode can have collection times as long as 0.1 μsec.

Circuits that separate neutron- and gamma-ray-induced events in organic phosphors have been described. In one circuit the initial part of the current pulse at the collector is selected by a short-circuited delay line and a crystal diode (*8*). Then it is combined by a

resistance-capacitance network with a suitably adjusted positive total-charge pulse derived from an earlier dynode. Thus scintillations produced by protons appear as positive pulses at the output while gamma rays appear as negative pulses.

Another method invented by Brooks uses positive and negative pulses formed by circuits having large and small time constants on the last dynode and collector of a photomultiplier, respectively (*9*). Thus the maximum amplitudes depend on phosphor decay time. The lengthened peak-height pulse is then subtracted from the total-charge pulse by a resistance-capacitance network. Neutrons produce positive pulses in organic scintillators; gamma photons produce negative pulses. With stilbene, resolution is effective for neutrons of energy greater than 0.5 Mev (electrons 0.13 Mev), while the liquid scintillator resolves proton and electron energies of 0.6 Mev and 0.16 Mev, respectively.

A simple but very effective method of discriminating between recoil protons and electrons in organic phosphors is illustrated in Fig. 3 (*10*). The anode is maintained at a potential generally 4–6 volts more positive than the last dynode, on which the signal is developed. During the initial, high-current portion of the pulse, space-charge effects limit the current that can pass from last dynode to anode; therefore much of the multiplied charge cannot leave the dynode, and it is driven negative. During the lower-intensity portion of the slow decay, however, space-charge limiting does not occur. A multiplied charge can now pass to the collector; this makes the dynode positive. Scintillations in organic phosphors above some minimum pulse amplitude produce positive pulses at the last dynode with neutron excitation, negative pulses with photon excitation.

Figure 4 was obtained in this way using an EMI 6097 phototube and a stilbene phosphor irradiated with Po-Be neutrons. Figure 5 was obtained in the same way from an RCA 6810 using *p*-terphenyl + POPOP in toluene. The method is equally effective with the Dario 53 AVP and the Du Mont 6292 photomultipliers.

This circuit provides good resolution for neutrons and gamma photons over an energy range of 0.5 Mev to >10 Mev in stilbene, or 1–10 Mev in liquid scintillators. At lower energies statistical variations in the numbers of photoelectrons available, in particular in the tail of the pulse, make assessment of decay time by the circuits difficult. Thus proton-electron resolution deteriorates. This also applies in neutron capture in boron-loaded liquid scintillators. The 2.4-Mev particle energy from the $B^{10}(n,\alpha)Li^7$ reaction produces a light pulse about equal in intensity to that of a 40-kev electron (*11*). In addition when the phototube gain is increased for such small pulses to a level at which space-charge limitation can operate, the tail of the pulse becomes a series of sharp spikes, each caused by a single electron. Each spike produces space-charge limiting, so that the circuit does not operate satisfactorily.

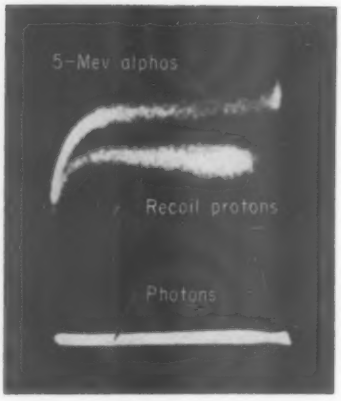


FIG. 7. SPACE-CHARGE DISCRIMINATION with NaI produces gamma pulses larger than alpha pulses

Limitations

To decide whether a pulse has originated from a neutron or a photon, an observation of decay time over a few microseconds is necessary. This limits the rate at which pulses can arrive. With the space-charge-limiting circuit described above and a 3-cm³ phosphor, a counting rate of ~15 cps is obtained for a flux of 30 n/cm²/sec from Po-Be. Preliminary results indicate that interference among pulses produces counting rates of the same order when the phosphor is exposed to ~14 mr/hr of radium gamma photons.

Inorganic Scintillators

We have made measurements to find out why inorganic phosphors like NaI(Tl) and CsI(Tl) show an effect opposite to that of organic phosphors when tested on the arrangement of Fig. 1. The shape of the light pulse was observed by photographing a number of alpha-particle- and electron-produced scintillations. The shapes of the light pulses obtained from NaI(Tl) excited by different types of particles agree with data of Eby and Jentschke (*12*), who reported the effects on pulse shape of thallium concentration and exciting particle (more particularly for heavily ionizing particles).

At the thallium concentrations normally used in NaI(Tl) phosphors (~0.001 molar) we find that the pulse can be considered as consisting of three parts: an initial spike with decay time constant of ~0.015 μsec, prominent under high specific ionization; a main fluorescent component with a rise time of 0.08 μsec; and an 0.23-μsec exponential decay substantially independent of the type of exciting particle. Under photon excitation the spike is relatively low, and a prominent feature is the relatively flat top of the main luminescence until about 0.15 μsec after initiation. This is shown in Fig. 6. For alpha-particle excitation, the pulse reaches a maximum promptly after its initiation and at once decays approximately exponentially.

The decay of CsI(Tl) appears to be generally similar in form to that of NaI(Tl), but the effect of thallium concentration appears much more marked. In a crystal giving poor amplitude resolution alpha-particle pulses are characterized by a very pronounced spike at the front edge followed by a fall almost to zero before the rise of the main part of the luminescence pulse. The spike was entirely absent under gamma radiation. In a crystal giving good amplitude resolution the pulses produced by fast electrons show a relatively slow rise to a maximum about 0.2 μsec after initiation followed by a decay with two exponential components of 0.4-μsec and 7-μsec time constants. Alpha-particle pulses rose promptly to their maximum and then fell roughly exponentially with 0.4-μsec decay time.

Storey, Jack and Ward have also studied pulse shapes in CsI(Tl) and interpret the luminescence decay as a fast exponential component, dependent on the type of exciting particle, and a second component with 7-μsec decay time, independent of the exciting particle (*13*). Decay times quoted for the fast component vary from 0.42

μsec for alpha-particle excitation to 0.7 μsec for electron excitation.

Discrimination Methods

When the space-charge-saturation system described above is applied to NaI(Tl) pulses, separation between different particle types can be had by suitable choice of multiplier voltages. The result is shown in Fig. 7. Since electrons produce larger pulses at the dynode than alpha particles or recoil protons, the method is of small practical value.

A more effective pulse-shape discrimination is obtained by comparing amplitudes of scintillation pulses passed through two different differentiating circuits. One way of doing this is to combine negative and positive pulses from multiplier electrodes as described earlier (*14*). This has the disadvantage that a large negative transient is passed to the amplifier.

Figure 8 shows an alternative method for the comparison using CsI(Tl). This can follow a conventional 2-Mc pulse amplifier. A positive total-charge pulse is provided by the amplifier and applied after attenuation to one grid of a difference amplifier. A differentiated peak-intensity pulse is formed by the delay line and its coupling capacitor and applied after ~1 μsec delay to the second grid. The input attenuator is adjusted so that the anode shows a positive excursion from quiescent only when a pulse of high peak intensity occurs.

Figure 9 shows the performance of this circuit with CsI(Tl) when the output is passed to stretching circuits as described in Fig. 1. Adjustment of the total-charge pulse allows rejection of photons or protons by a pulse-amplitude discriminator. Similar circuits operate directly on the pulses developed at the output of a high-gain photomultiplier and can be used for both NaI(Tl) and CsI(Tl).

The rejection of interfering gamma radiation is more easily achieved with inorganic than organic phosphors. An interfering pulse occurring during the assessment of decay time of an inorganic phosphor apparently lengthens decay, and this leads to rejection of a few protons. This is usually less serious than the situation with organic phosphors in which interference in intense gamma fluxes leads to the registration of a small fraction of the gamma pulses as protons.

Potential Value

The considerations that affect pulse-shape resolution are in general the same as those that affect amplitude resolution. In large organic scintillators, pulse-shape resolution may also be impaired by multiple events in which carbon recoils can play a part. The development of circuits that make best use of the photoelectron scintillations is continuing.

Since phosphors in general use are chosen because of their high light outputs, it seems likely that they offer the best opportunities for pulse-shape discrimination. But a new survey of less widely used materials based on this feature would be worthwhile. It seems possible that liquid scintillators with more long-lived components may emerge, producing pulses that are easier to treat electrically.

Of the inorganic scintillators specimens of LiI(Eu) and LiI(Sn) have been tried to see if the 4.8-Mev energy from $Li^6(n,\alpha)H^3$ reactions can be distinguished from a gamma-ray background or induced iodine beta activity. Pulse-shape resolution, if any, is poor. Since discrimination can be obtained with thallium-activated alkali halides such as CsI, NaI, KI and KBr, the currently abandoned LiI(Tl) may repay further study.

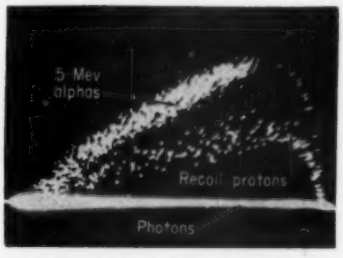


FIG. 9. PHOTONS, PROTONS and alpha particles produce three groups of oscilloscope flashes after discrimination by circuit of Fig. 8

* * *

The author acknowledges with gratitude the able assistance of D. W. S. Smout and M. Wasson with many investigations appertaining to scintillation decay times and the interest and encouragement of W. Abson.

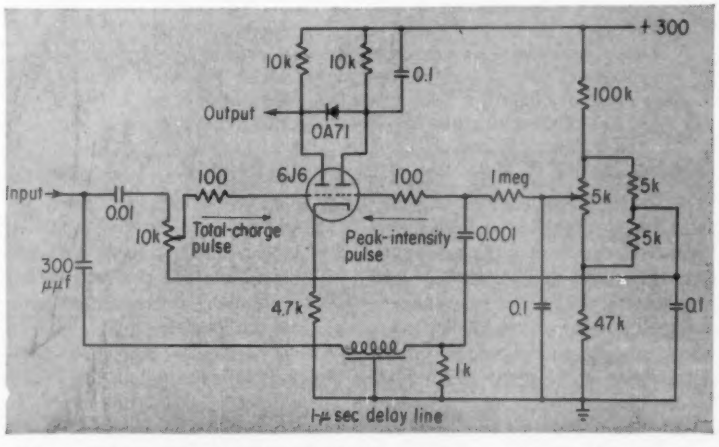


FIG. 8. CIRCUIT FOR CsI DISCRIMINATION compares total-charge pulse with peak-intensity pulse and produces output only for high peak intensity

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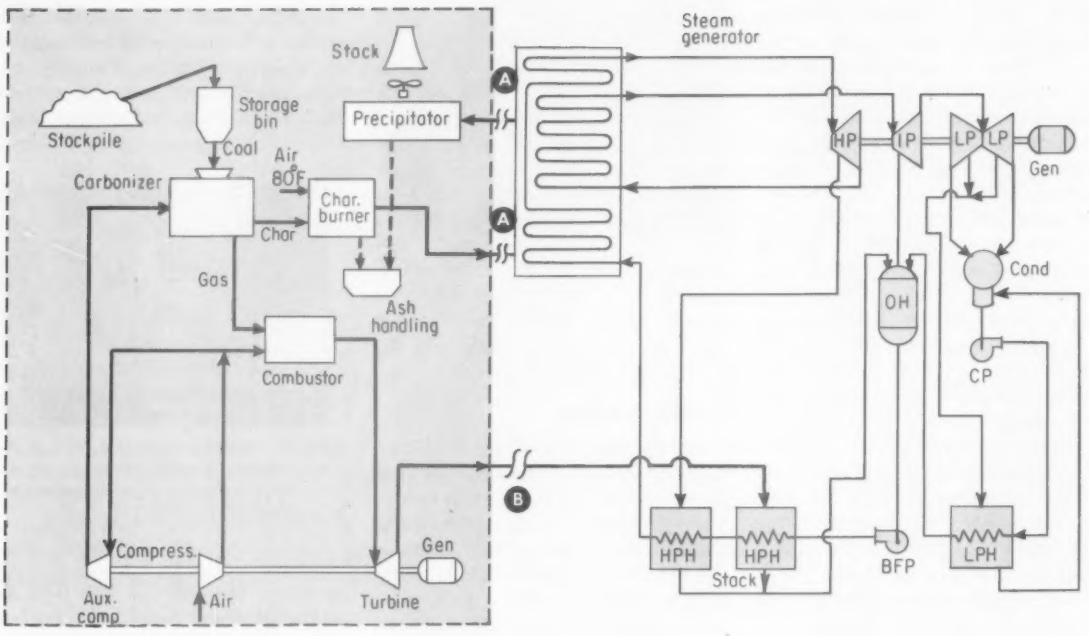
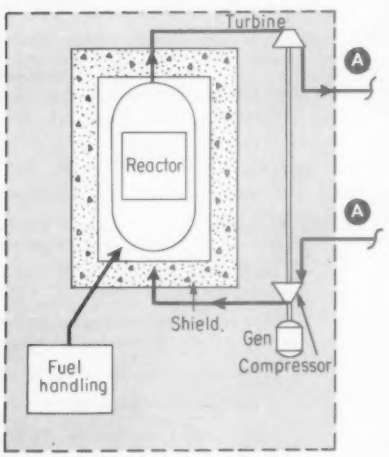
The Future of





Whether Advanced Coal-Burning Plant . . .

Or Gas-Cooled Reactor . . .

Both Will Use Same Steam Cycle

Both will also produce electricity through gas-turbine hooked up in binary cycle with steam system. Reactor has no connection equivalent to "B," since turdine-exhaust gas is returned directly to reactor insteab of exhausted to atmosphere through first feedwater heat exchanger. However, to compete, the reactor must achieve 2,000° F fuel temperatures, attain burnups beyond 15,000 Mwd/ton. To do this, best combination of materials appears to be UO_2 fuel moderated by graphite and cooled by helium

A REALISTIC WAY to judge the prospects of the gas-cooled-reactor concept, or of any reactor concept for that matter, is to compare it with the advanced-design coal-burning plants with which it will have to compete in the future. This is especially easy to do for the gas-cooled concept because the two kinds of plants —coal-burning and gas-cooled reactor —will have nearly identical thermal cycles (see Fig. 1). To the best of our knowledge the coal-burning plants of 1980 will use a high-performance binary gas-steam cycle (see box, p. 98) to convert heat into electricity. It turns out that the best cycle for a plant powered by a high-temperature gas-cooled reactor will also be a gas-steam cycle very similar to the conventional-plant cycle. Because of this similarity an economic comparison is made much simpler; it becomes a question of choosing between a coal-burning heat source and a gas-cooled-reactor heat source.

We find that to compete with the coal system the reactor would have to achieve the following goals:

- Fuel elements that can run at 2,000° F, deliver gas at temperatures above 1,500° F and survive to burnups beyond 15,000 Mwd/metric ton.
- Fuel costs in the neighborhood of 2 mills/kwh.

Gas-Cooled Reactors

By WILLIAM S. BANKS
Allis-Chalmers Manufacturing Co., Washington, D. C.

• A plant size in the range of 1,100–1,500 Mw(th).

The Experimental Gas-Cooled Reactor (EGCR) to be built (by Kaiser Engineers and Allis-Chalmers) at Oak Ridge will provide some of the needed experience, ultimately to temperatures of 1,200° F, and will contain a number of experimental loops. The High Temperature Gas-Cooled Reactor (HTGR) (to be built by General Atomic) will provide experience up to 1,382° F. Beyond that, it will be necessary to build a large prototype plant to operate up to 1,500° F. Construction should begin by 1962 so that when the first high-temperature test elements come out of the EGCR a core can be ordered for the prototype. This prototype should be a fairly large plant, of perhaps 150 Mw(e).

The prototype would start operation in 1966 and construction of a 1,100-Mw(th), (or larger) plant should begin in the same year. The full-scale plant would be ready for its first fuel loading in 1970. With 11 years of fuel development concentrated upon a specific goal, 7 years' operation of the EGCR and HTGR and 4 years' operation of the large prototype, the full-scale plant should be fully competitive with the best fossil-fired plants, not of previous years but of its own time.

Evaluation Criteria

Many criteria have been suggested for the selection of promising reactor systems for development, and no single system could be expected to rank high on all of the suggested criteria. Here we will adopt four such characteristics of merit, and take it as self-evident that any reactor system that ranks high in these characteristics will eventually become economic under any reasonable system of computing power costs. However, we must note that the converse is not necessarily true—systems which do not meet these standards may possess equal promise. Our four indices are:

• **High coolant temperature.** A coolant temperature that is high, not only in relation to other nuclear systems but in relation to fossil-fired plants, is an important figure of merit. Increased efficiency reduces operating costs and, up to a point, capital costs as well. Of course, for any given system there is a coolant temperature that represents the best compromise between thermal efficiency and materials efficiency.

• **Working fluid as coolant.** A reactor coolant that is also the thermodynamic working fluid in the power-conversion cycle eliminates the need for heat exchangers, which represent a significant cost item in any nuclear system. Also, to compete with future fossil-fired plants the reactor coolant should be suitable as the high-temperature, low-pressure working fluid in a binary cycle.

• **Early construction.** Suitability for early construction is necessary because of the great importance of acquiring experience. An attractive conceptual design that requires years of research and development may never have the opportunity to compete with more prosaic types on which the same amount of time has been spent on construction and operating experience.

• **Low fuel cost.** It is absolutely necessary that nuclear fuel costs be less than that for coal, which is above 3 mills/kwh in most of this country at present. A nuclear plant with incremental costs below the conventional plants in the power distribution system will be base-loaded. The resulant high utilization factor reduces capital charges.

Now, the objection will immediately be made that, although these criteria may be good, another is available that is both simple in application and universal in scope—namely power cost. However, as a recent NUCLEONICS editorial by Weinberg (*15*) pointed out, power-cost computations generally reflect only the economic and political forces of the past and the present and may be subject to serious shortcomings as a basis for decisions that reach out into the distant future.

We present an interesting illustration of this point in the box on p. 101. We show that nuclear power from several reactor types could be made economic in the United States today, by simply changing the method of taxing power production so that the power is taxed directly as consumed instead of indirectly against the return upon investment. In the example given the change from the traditional method of taxation does not affect the cost of power as seen by either producer or consumer.

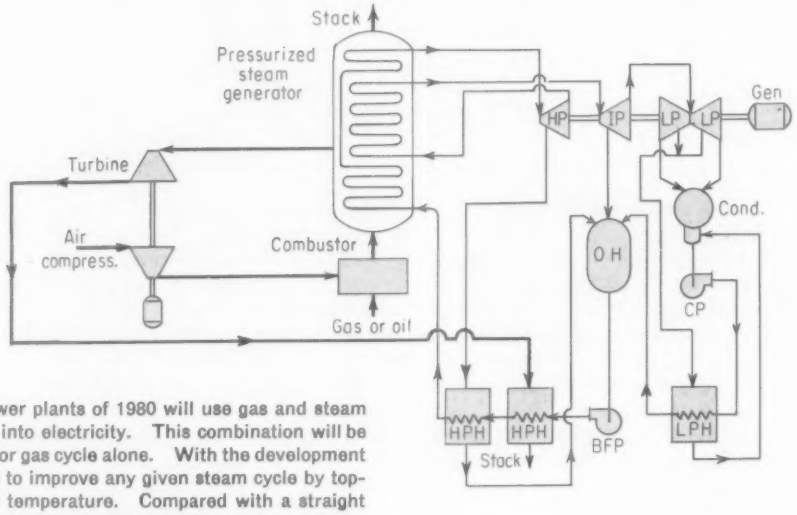
Now, we do not intend to suggest or imply a need for change in tax policies. These policies may be preferred to any others by the nation as a whole for a myriad of reasons unrelated to nuclear power. The important point is not whether tax laws should or should not be revised to make nuclear power competitive, but rather that decisions made today based on cost alone may prove to be quite unsound if tax laws change as drastically over the next fifty years as during the last. Although the tax laws and accounting practices of the year 2009 cannot be predicted with any certainty at all, the Second Law of Thermodynamics will be unchanged in 2009. And any reactor system which meets the four criteria listed above must eventually become economic under *any* reasonable conditions.

Reactor-Coolant Evaluation

If we examine the reactor coolants suitable for a direct cycle with respect to the criteria of high temperature and early construction, we find that direct-cycle energy-conversion equipment already exists for water, mercury and air.

Nuclear superheaters, now under development, could be used either with a boiling-water reactor or in a Loeffler cycle, applications sure to be useful for small plants. However, although further improvements in steam technology are beginning to show diminishing economic returns, it does appear

Tomorrow's Coal-Burning Plants



The conventional fossil-fuel power plants of 1980 will use gas and steam turbines in series to convert heat into electricity. This combination will be more efficient than either a steam or gas cycle alone. With the development of gas turbines, it will be possible to improve any given steam cycle by topping it with a gas cycle at higher temperature. Compared with a straight gas cycle, the gas-steam binary cycle will accept heat at the same maximum temperature but will reject it at a much lower average temperature. By 1980 the steam cycle portion of such plants will probably be operating at 1,400° F and 7,000–10,000 psi. Even at these extreme conditions the plant efficiency would only be about 10% higher than today's modern plants; topping with a gas turbine would result in an additional 5–7% (see Appendix).

The first step toward the gas-steam binary system would probably be a pressurized steam generator (see figure above) in which some of the high-temperature combustion gas drives a turbocompressor which pressurizes the combustion air to several atmospheres.

likely that most of the large coal-fired steam plants a few years hence will be designed for operation above the critical point; hence a subcritical nuclear superheater may prove obsolete for large plants before it can be developed. A reactor cooled by steam in the supercritical state would not meet the criterion of suitability for early construction. Also, we foresee that single-fluid cycles are likely to give way to binary cycles in future plants. To compete with such fossil-fired heat sources, a reactor will have to supply its heat directly to the high-temperature working fluid. It therefore seems prudent to develop a reactor with a suitable high-temperature working fluid, rather than the low-temperature fluid, as its coolant.

Binary cycles in which mercury serves as the high-temperature fluid and steam as the low-temperature fluid have been in service for over thirty years. However, the mercury turbines were never completely satisfactory and most of them have been retired from service.

A great amount of experience has been accumulated with gas turbines operating on combustion products and air. Pure nitrogen, which is preferable to air in a reactor because of its lower chemical activity and reduced argon content, would require only insignificant deviations from proven machines, so that nitrogen is a convenient standard for comparing gaseous reactor coolants.

We have said that cost estimates for nuclear power plants are not a good basis for very-long-range planning. However, they are useful and even necessary to the design engineer as a basis for comparison, over a limited range, of specific designs. It is of interest to make such an economic comparison between gases as reactor coolants. Hydrogen is outstanding among gases as an agent of heat transfer and heat transport, but is usually not considered for immediate development because of the materials compatibility and safety problems. After hydrogen is rejected, the range of choice quickly narrows to carbon dioxide and helium. Both these gases offer better thermal performance than nitrogen. Helium has better heat *transfer* properties than carbon dioxide but carbon dioxide has the better heat *transport* capability. The result appears to be an economic standoff. If we anticipate a future development to the higher temperatures at which carbon dioxide becomes very active chemically, helium appears to be the practical choice.

In fact the chemical inertness of helium helps to offset its disadvantage of low volumetric heat capacity. A low-heat-capacity gas requires a large temperature rise through the reactor core, which emphasizes hot-spot factors. The inertness of helium, however, minimizes the chemical effects of these hot spots and allows the fuel-element designer to concentrate upon the structural problems of the fuel element.

Even so, helium presents a number of problems as a reactor coolant. First, although it is chemically inert, chemical activity in general tends to increase exponentially with temperature, so that reactions of impurities in the helium become very important at the temperatures of interest.

As to the question of future availability, a small fraction of the helium that is at present vented to atmosphere at the wells could supply a number of large helium-cooled reactors for at least 20 years (*16*).

The containment of helium is not easy and careful attention to the problem is required during design and construction. But again it has been shown

(*17*) that a helium leak rate of 1% per day in a large plant would contribute only 0.016 mill/kwh to the power cost; it appears one can make the leakage rate this low without undue expense.

The fact that large rotating machinery for helium has not yet been built is another reason for uncertainty. However, there is considerable confidence that acceptable turbomachinery can be built with our present knowledge (*18–20*). The sonic velocity in helium is about three times that in air, so that tip speeds can be limited by the blade stress rather than by the approach to sonic velocity as in air or carbon dioxide. Thus, although the required number of stages is usually greater with helium because of its higher specific-heat ratio, the freedom from Mach-number limitations means that the number of stages does not become excessive.

In summary, helium ranks high as a reactor coolant on each of the first three indices of merit. Because it is chemically inert, it is probably suitable for service at higher temperatures than any of the active coolants. It is better than air as a heat-transfer and -transport medium, but its properties are similar enough to those of air so that the turbomachinery can be constructed with present knowledge. As a high-temperature thermodynamic working fluid (*19*) helium is entirely satisfactory. Since it can be used in binary cycles with steam as the low-temperature fluid, it is well equipped to compete with the binary-cycle fossil-fired plants of the future.

One often hears the comment that the heat fluxes, and consequently specific powers, in gas-cooled reactors will be so low that high uranium inventory charges and high capital cost of the reactor will offset the advantage of the gaseous coolant. Figure 2 indicates the range of heat fluxes that may be obtained in reactors operating with a film temperature drop of 500° F. The important effect of geometry is not included in the figure, and for that reason a range of values is given. Evidently the heat fluxes and hence the specific powers obtainable at reasonable pressures are quite good.

High-Temperature Fuel

The problem in fuel-element design most basic to gas-cooled reactors is that of structural stability under design heat flux. When a fuel-element surface approaches another surface, either another fuel element or some other structure, the flow of the coolant gas between the surfaces diminishes and the temperature of the fuel surface at that point increases. Unless the fuel geometry has been carefully designed—and such designs are difficult to fabricate—the increased local temperature increases the deflection, which further increases the local temperature. The process is therefore self-perpetuating for gas-cooled reactors.

Other reactor types are not bothered as much by this problem. For example, if the coolant is a liquid operating close to its vapor pressure, boiling in the region of restricted flow increases heat-transfer rate which lowers the temperature and reduces the deflection.

The tendency toward instability in gas-cooled reactors is further aggravated by the effect of asymmetrical geometry on circumferential temperature variations around the fuel rods. A theoretical treatment of turbulent heat transfer (*21*) for a cluster of seven round elements indicates, on the basis of some very broad assumptions, that the average circumferential temperature at a given axial location, when weighted by the heat flux, is greater than that derived by a simple heat balance along the coolant path to the point in question. The effect results from circumferential temperature variations that arise from nonuniform velocity gradients, which in turn are caused by lack of geometrical symmetry.

Early analysis indicated that this effect might double the average temperature difference between the fuel surface and bulk coolant for elements of the EGCR type: however, test results show that with optimum spacing of the elements the increase can be limited to something like 5%.

Besides reducing the effective transfer coefficient and thus necessitating larger hot-spot allowances, the circumferential temperature variations lead to bowing of the elements in the direction of the hot streak. The temperature structure is quite sensitive to spacing of the elements: a movement of 10 mils can increase the temperature difference across a single element by several degrees. If the element is much over two feet in length each degree of temperature difference may in turn deflect the mid-point of the element by a mil or more; this deflection may exceed the threshold of instability. Designing to overcome unstable deflections is made more difficult because the increase in the second moment of cross-section area increases the thermal moment in the same degree that it increases the stiffness of the section. For these reasons, the unsupported length of the fuel is one of the most critical parameters in the design of a gas-cooled reactor with metal-clad fuel.

Fission product gas. While the problem of thermal stability is perhaps most basic to the design of fuel elements for gas-cooled reactors, there is a second major problem that is basic to the design of all high-temperature, solid-fuel reactors; this is the containment of the accumulated fission gases. The problem is aggravated in the gas-cooled concept by the large temperature drop at the surface, which produces a higher average fuel temperature for the same fuel geometry and heat flux. The higher temperature encourages release of fission gases and also increases their pressure. If the oxide fuel proves capable of retaining most of the gases, metal claddings of reasonable thickness (e.g., 0.020 in.) should serve for exposures of 10,000 Mwd/metric ton or greater at approximately 2% enrichment. However, if all or most of the gas is released from the oxide, cladding thickness and consequently enrichment will have to be increased substantially.

The sudden loss of coolant pressure becomes an important problem with the buildup of fission gases. Indications are that as the internal temperature of the oxide approaches the melting point, the gas release increases rapidly; to achieve economic fuel exposures it may prove necessary to limit heat flux to keep the fuel temperatures low enough so that a significant fraction

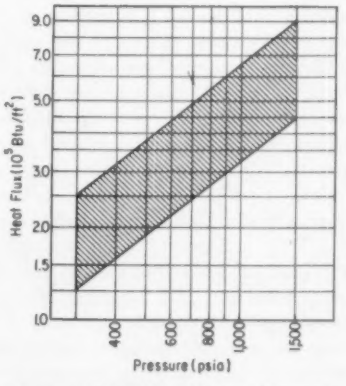


FIG. 2. HEAT FLUX in high-performance gas-cooled reactors vs. pressure

of the fission gas stays in the oxide. A broad program of fuel irradiation tests is under way in support of the Experimental Gas-Cooled Reactor, which, it is hoped, will establish relationships between fuel temperature and gas release.

Prospective materials. Both the EGCR and the HTGR are expected to attain gas temperatures of 1,000° F with metal cladding. Accumulation of experience with hot spots and high-temperature alloys for cladding may make possible gas temperatures above 1,200° F. However, to realize the potential for development discussed earlier, it will be necessary to develop a fuel element that can operate around 2,000° F and deliver gas temperatures above 1,500° F. Such fuels will almost certainly be ceramics, coated with another ceramic or with a cermet.

If a fuel material cannot be found that retains most of its fission gas at high temperatures, two general approaches are open. It may prove practical to bleed the gases as they are released—the approach being taken in the High-Temperature Gas-cooled Reactor (HTGR). The second approach is to operate with a radioactive system—allow the gases to diffuse out of the elements into the gas stream and remove them by a filtering system. Fuel elements that could be used in such a system have already been made and tested above 2,000° F. This approach will be explored in the Turret Reactor, a 3-Mw(th) reactor experiment being planned by Los Alamos Scientific Laboratory and Sandia Corp. (*22*).

The fuel costs for oxide-and-stainless-steel fuel elements are expected to be less than 3 mills/kwh (*23*, *24*), costs which meet the fourth of the indices of merit listed above. It is unlikely that the fuel material of any of the very-high-temperature ceramic elements will be any cheaper to fabricate; but neither is there reason to expect significantly higher fabrication costs. If the fission gas can be removed, very high burnups will be possible, which will result in very low fuel costs per kilowatt-hour.

HTGR will operate on uranium-235, thorium, and later uranium-233, mixed as carbides into solid homogeneous elements clad with graphite. These cores will provide important information about the thorium cycle, the stability of ceramic cores to temperature and radiation, fission-gas diffusion rates, graphite-cladding stability and permeability, and the feasibility of removing fission gases as they are formed.

The Pebble Bed Reactor (*25*) which is undergoing preliminary design and development by Sanderson and Porter for the AEC and the Bureau of Mines also has a solid homogeneous core of thorium-uranium fuel mixed with graphite moderator. The elements are spherical in shape, treated with an impervious coating such as silicon carbide. This geometry has the attractive possibility of combining very efficient heat transfer with mass production and mass handling of fuel.

Moderator Choice

Among the moderators available for very-high-temperature gas-cooled reactors, graphite appears to be most practical for early construction.

Graphite possesses both good mechanical and good thermal properties. However, when it is irradiated above 1,000° F it contracts slightly (in contrast to its low-temperature irradiation behavior); this raises some severe structural-design problems.

At temperatures of 1,500° F, graphite is oxidized by most of the impurities normally encountered in helium. Several solutions to this problem are possible. One is to replace the core if necessary, which also eases core structural-design problems; this is the solution employed by the British in their Advanced Gas-Cooled Reactor. Another solution to the oxidation problem is to coat the graphite. Silicon carbide is an attractive possibility as a coating material; its oxidation resistance has been established by tests in air up to 2,000° F, but its behavior under radiation is unknown.

Power-Plant Cycles

A parametric study (*26*) of gas-cooled reactors by the Hanford Atomic Products Operation of the General Electric Co. concluded that a simple gas-turbine cycle at 1,300° F probably has no advantage over a steam cycle at 1,100° F. As we have seen, however, a combination of the two, since it could increase the difference between the maximum and minimum temperatures of the cycle, is better than either alone; the improvement is as good for the nuclear plant as for the conventional plant (*27*).

Experience exists with hundreds of gas turbines over millions of hours of operation; however, nearly all this experience applies to units of 30 Mw or less in size and no units have been built which approach central-station size. Nevertheless, large units are not required in central-station applications to exploit the thermodynamic advantage of the heat available at temperatures above the practical steam-cycle range. An example is shown in Fig. 1. The hot gas from the reactor expands through a turbine and exhausts to a heat exchanger where steam is generated for the steam cycle. The turbine drives a compressor that restores the pressure lost in the turbine and circulates the gas. Almost all the energy dissipated through inefficiencies in the turbine and compressor is returned to the gas as heat; the only energy lost to the system is a percent or less in mechanical and radiation losses. A practical problem would be encountered in the parallel operation of the blowers, which are aerodynamically coupled to their drivers. An electric generator is coupled to the gas turbine.

Comparison of Future Plants

If we compare the gas-cooled nuclear plant (see Fig. 1) with the combined gas-steam coal-burning plant (Fig. 1), we see that the systems are basically very similar. The reactor complex competes almost directly with a coal-handling complex that consists of coal stockpile, handling facilities, carbonizer, combustor, char burner, ash-handling facility, precipitator and boiler fan. The costs of some of these components have been estimated (*10*) as follows:

	$/kw(e)
Coal handling	30.0
Carbonizer	3.0
Forced-draft fans	1.5
	34.5

With the additional costs of the combustors, precipitator and ash-handling equipment the cost of the coal complex will probably exceed $40/kw in 1958 dollars in many localities.

If the nuclear plant can achieve an incremental power cost which is 1 mill/kwh less than that of the coal-fired plant, the nuclear plant is economic, up to approximately the point that the cost of the reactor with its equipment, shielding and containment but without its coolant system exceeds that of the coal-handling

complex by

$$\frac{0.001 \times 8{,}760 \times 0.5}{0.14} = \$31/\text{kw}.$$

A plant factor of 50%, which is greater than the U. S. average (*3**), and a capital charge rate of 14% are used in this calculation.

From the above figures, it appears that a utility would find a high temperature, gas-cooled nuclear plant attractive at a cost of about $70/kw for the reactor complex if the incremental power cost were 1 mill/kwh cheaper than coal, or at about $100/kw (1958 dollars) for a 2-mill/kwh advantage. If we accept the coal rate of 0.65 lb/kwh of 12,500-Btu coal that has been estimated (*1*) for the best stations in 1970, the fuel cost for those stations which pay $12.50/ton for coal is 4 mills/kwh. If a high-temperature fuel element can be developed whose cost is 2 mills/kwh, a cost of $50 million (in 1958 dollars) would be justified for the reactor complex (only) of a station with 500 Mw(e) [or about 1,100 Mw(th)] capacity.

It has been estimated (*23*) that a gas-cooled nuclear plant, producing 600 Mw(th) and 200 Mw(e) net, could be built to operate at 1,000° F gas outlet, with stainless-steel and oxide fuel elements, for $73 million (1958 dollars). Of this, about $30-million is attributable to the reactor complex. The decrease in cost per unit capacity with increased steam-plant size reported by Porter and Hart (*3*) follows a 0.72-power relationship, which is close to the 0.70-power law often used (*28*). On this basis, a 1,100-Mw(th) thermal-reactor complex would cost

$$\left(\frac{1{,}100}{600}\right)^{0.72} \times 30 = \$46.4\text{-million},$$

which is well within the cost limit for a reactor with a 2-mill fuel-cost advantage.

The fuel cost for this 200-Mw(e) plant is estimated to vary between

* The McKinney Panel (*29*) concluded that the typical power system operates at a yearly plant factor of 60%, and that the U. S. average in 1954 was 62.9%. However, because the total capacity approximately doubles every decade, the lifetime plant factor of each individual plant is much lower, averaging about 43%. The McKinney Panel calculates that a nuclear plant that enjoys three times the use of the conventional plant up to the twenty-first year of its thirty-year life would achieve a lifetime plant factor of 49.8%—or about 50%.

Does the Tax System Penalize Nuclear Power?

A simple change in our tax laws—a tax on power consumed rather than on power-plant investment—could make nuclear power economic today. We do not advocate such a change, but it does point up the unreliability of using power costs as the single criterion for judging reactor types.

Since the capital investment in nuclear plants is greater than in conventional plants and since we tax the return on capital investment, the consumer pays more money for tax when he buys nuclear power. An alternative scheme that taxes the power consumed would be fairer to nuclear power and would allow designers to optimize in the direction of larger plant investment.

Basically, the designer of any power plant attempts to optimize the expenditure of three resources: fuel resources over the life of the plant, labor resources over plant life, and capital resources at the beginning of plant life. The market prices of these resources are the weighting functions for optimization. The levying of taxes on power production against the return on capital has the effect of nearly doubling the importance of investment to the plant designer. As an illustration, consider the following power-cost breakdown for a conventional plant.

Conventional plant	*Investment return taxed (mills/kwh)*	*Power consumption taxed (mills/kwh)*
Fuel and operation	4	4
Capital charges		
Return to investor	2	2
Tax on investment return	2	0
Total cost seen by producer	8	6
Tax on power consumed	0	2
Total cost seen by consumer	8	8
Revenue to government	2	2

Of the four mills' capital charge, nearly half is paid in taxes. In each instance, the investor receives the same return, the consumer pays the same tax, and the government receives the same revenue. But the importance of investment in optimizing plant design when power consumption is taxed is half that when investment return is taxed.

Now if we have a nuclear plant with capital cost twice that of the conventional plant but with fuel and operating costs only half as great, the costs are:

Nuclear plant	*Investment return taxed (mills/kwh)*	*Power consumption taxed (mills/kwh)*
Fuel and operation	2	2
Capital charges		
Return to investor	4	4
Tax on investment return	4	0
Total cost seen by producer	10	6
Tax on power sold	0	2
Total cost seen by consumer	10	8
Revenue to government	4	2

The return to the investor is twice as great on twice the investment, so that the rate of return is the same in both instances. It may be argued that it is to the government's interest to develop nuclear power since it stands to realize more tax revenue than from conventional power. Certainly the argument against early development of nuclear power because it is not "needed" would no longer apply if the tax method were changed.

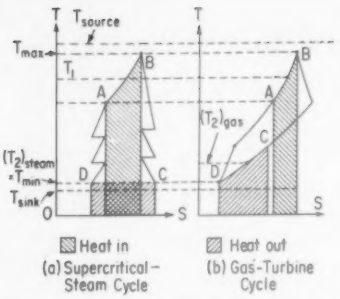


FIG. 3. COMPARISON of thermal cycles

3.7 mills/kwh for a burnup of 5,000 Mwd/metric ton and 2.1 mills/kwh for a burnup of 15,000 Mwd/metric ton; at the latter figure the necessary fuel-cost advantage would be achieved.

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APPENDIX—Future Development of Coal-Burning Steam Plants

The thermodynamic advantage of the binary cycles may be seen by recalling the equation for the Carnot efficiency of an ideal heat cycle:

$$\text{eff}_{\text{Carnot}} = \frac{T_1 - T_2}{T_1}$$

Of two cycles, to which heat is added at the same average temperature T_1, that cycle which rejects its heat at a lower average temperature T_2 attains greater efficiency.

Figure 3 shows the temperature-entropy diagram of two regenerative cycles without reheat or intercooling, a supercritical condensing (steam) cycle and a non-condensing gas-turbine (Brayton) cycle. Heat is added to both systems at the same average temperature T_1, between points A and B. Rejection of unavailable energy takes place at an average temperature T_2 between points C and D, and T_2 is lower in the case of the steam cycle because all heat rejection is accomplished at the same temperature. Thus the condensing cycle is more efficient when operating between the same two temperatures.

Now if, as has been seen, there are practical limitations to the upper temperature with the condensing cycle (partly due to the high pressures involved) the low-pressure gas cycle may be used at temperatures above those of the steam cycle. Heat is added at some average temperature T_1 to a gas at relatively low pressure. The heat which is rejected from the gas cycle is added to the steam cycle. The final rejection of unavailable energy by the steam cycle is all accomplished at the lowest possible temperature by condensation. The selection of steam temperatures does not control the plant efficiency since this efficiency is primarily determined by the average gas temperature while heat is being added.

There are some practical difficulties involved in the use of binary cycles. The cycle shown on p. 98 is adaptable only with gaseous fuels, or certain clean oils, both of which are scarce as compared to coal, or with oils which have been specially processed (*12–14*). In a combined gas-steam cycle which burns coal, it is necessary to gasify the coal, expanding the products of the clean gas combustion through the turbine and burning the char in a boiler at atmospheric pressure (Fig. 1).

Harlow (*1*) has extrapolated past trends in steam plant conditions to 1980, and concluded that the probable contemporary advanced design of a fossil-fuel steam plant of that time will be a 750 Mw(e) plant, operating on a binary (combined) cycle using both gas and steam turbines. Steam conditions of 1,400° F and 7,000 psi at the throttle are anticipated, with liquid-metal reheating to 1,300 and 1,250° F.

More recent experience (*2*) suggests that these steam conditions may not be reached by that time due to difficulties in developing high-temperature materials; however, this will not necessarily detract from the over-all plant efficiency because this efficiency will be primarily determined by the temperature at the gas turbine throttle.

From a similar projection, Porter and Hart (*3*) obtained the same 1,400° F temperature at a higher pressure (10,000 psi) in a larger [1,000 Mw(e)] unit. They foresaw only a ten percent improvement in steam cycle performance with these very difficult conditions, and concluded that it does not appear possible to realize in the future the great gains in steam technology of the past 25 years. Thus steam technology is likely to advance sufficiently to make supercritical cycles economic, but the degree of further development is open to question because of increasing technological difficulties and decreasing economic returns. Porter and Hart also point out that an air-steam binary cycle at present-day temperatures would provide 70% of the gain that could be expected in 22 years of difficult development from the steam cycle alone.

A number of binary air-steam cycles (*4–11*) have been proposed. The most efficient of these employs a gas turbine driving a compressor which pressurizes the combustion air to several atmospheres and delivers it to the boiler, as shown on p. 98. Heat transfer rates are much better than at atmospheric pressure and the pressurized boiler is smaller and cheaper than an atmospheric unit. Some of the combustion products are withdrawn from the boiler and expanded through the gas turbine. Heat which does not go to the gas turbine generates steam, and that rejected by the gas turbine heats the feedwater before passing out the stack. Besides the reduction in boiler size the plant efficiency is increased by 5 to 7% over that of the steam cycle alone.

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Kandiah Discriminator Permits Simplified Monitor Circuit

By M. H. GOOSEY
E. I. du Pont de Nemours & Company
Savannah River Laboratory, Aiken, South Carolina

The Kandiah discriminator (*1*) is sensitive enough to operate directly from the output of a photomultiplier without the use of an amplifier. This has enabled us to construct a greatly simplified radiation monitor that has adequate stability for many applications. The monitor is shown in Fig. 1.

An integral discriminator is often needed for radiation monitors using scintillation detectors so that low-energy radiation, noise, etc., can be excluded from the count. Since a discriminator not of the Kandiah type requires a large input pulse to achieve high stability, a pulse amplifier is required after the photomultiplier. The design of such a pulse amplifier is critical since any noise or distortion that it introduces is added to the desired signal. This problem is avoided by the use of the Kandiah circuit.

The circuit of the simplified radiation monitor is shown in Fig. 2. The discriminator, which is similar to the Chalk River version (*2*) of the Kandiah circuit, has a stability of 1% at a 100-mv signal level and a linearity of 3%. The range of input voltage is affected slightly by component tolerances. For the values given in Fig. 2, it is about 100 mv for the most sensitive setting of the discriminator control and about 1.2 volts for the least sensitive setting.

The positive output pulse from the discriminator is used to operate a cold-cathode-tube counting-rate circuit (*2*). A negative pulse is available for operating a scaler.

The thermistor-resistor network, in the grid circuit of the cathode follower in the probe, provides first-order compensation for changes in the gain of the photomultiplier caused by ambient temperature variations and can be omitted in applications where the ambient temperature is relatively constant during the measuring interval.

The full-scale current available from the counting-rate circuit is 5 μa for the component values given in Fig. 2. Sufficient current can be obtained to operate a 20-μa meter at the sacrifice of some linearity of the output reading (*3*).

Stilbene crystals are normally used for beta monitoring while sodium iodide crystals are normally used for gamma-ray detection.

Several monitors of this type have been in operation for the past two years on a 24-hr-a-day basis and have proved to be reliable and robust instruments.

* * *

The information contained in this article was developed during the course of work under contract AT(07-2)-1 with the U. S. Atomic Energy Commission.

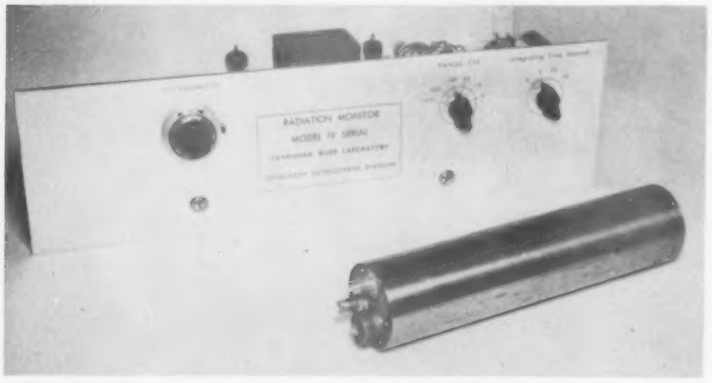

FIG. 1. MONITOR includes discriminator and counting-rate meter; also shown is probe containing photomultiplier and cathode follower

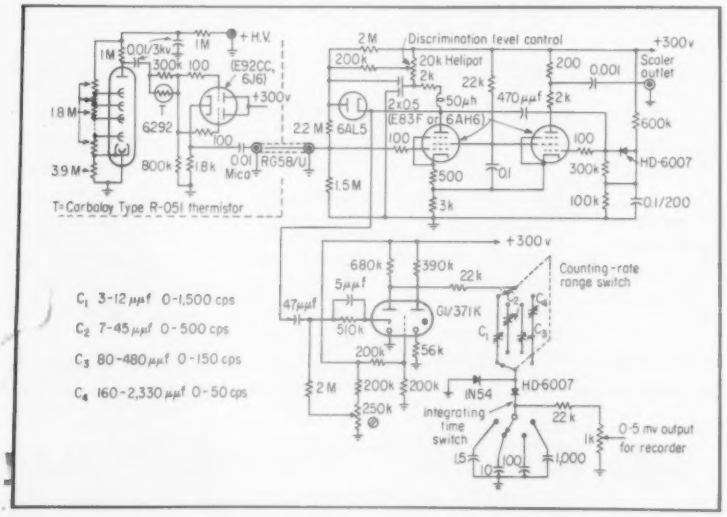

FIG. 2. MONITOR CIRCUIT includes cathode follower, Kandiah discriminator and ratemeter

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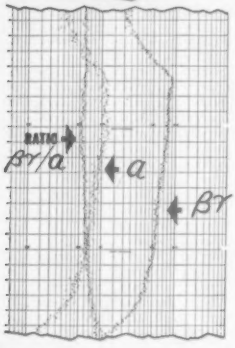

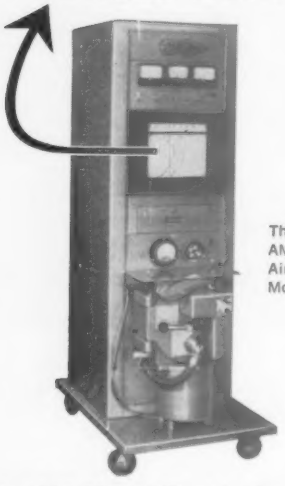

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Induced Antimony Activity in Mylar

C. A. ACCARDO, H. W. HENDEL, R. G. LAUTTMAN and M. N. STEIN
U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey

A radiation hazard may exist when large amounts of Mylar are subjected to high-dose neutron bombardment because of induced antimony activity. Also, in the case of Mylar films that are used in electrical components, ionization effects and beta activity may affect the operating characteristics of these components and cause adverse effects on the electronic circuits.

Mylar films that were irradiated in the Brookhaven research reactor to study the effects on the dielectric properties were found to become activated because of the presence of antimony in the plastic material. Several samples of type A and type D Mylar film enclosed in evacuated quartz vials were irradiated in the water-cooled hole where the thermal flux was of the order of 5.2×10^{12} neutrons/cm²/sec with total doses of the order of 10^{18} nvt (thermal).

The activity of the samples after washing was the same as before washing, thereby eliminating the possibility of surface contamination. Counting measurements indicated a half-life of approximately 60 days. Energy spectra from a NaI (Tl) gamma-ray spectroscopic analysis showed photoelectric peaks whose energies and relative heights corresponded to the decay scheme of Sb^{124}. Both chemical analysis and emission spectroscopic analysis confirmed the presence of antimony. Calculations showed that the amount of antimony in these samples was about 200 parts per million by weight. Similar results, obtained from studies on irradiated adhesive products, have been reported by Lukens.*

The Sb^{124} is produced in an (n,γ) reaction in Sb^{123} (relative abundance 43%). In addition to the 60-day activity of the Sb^{124}, there is a 2.8-day activity due to the Sb^{122} arising from an (n,γ) reaction in Sb^{121} (57% abundance). Since the cross section for this reaction is 6.8 barns, the initial activity will be of the order of 0.2 mc/gm.

* H. R. Lukens, Jr., "The Activation of Antimony in Adhesive Products," NUCLEONICS **17**, No. 1, 83 (1959).

Cab-O-Sil Suspensions for Liquid-Scintillation Counting

By D. G. OTT, C. R. RICHMOND, T. T. TRUJILLO and H. FOREMAN
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

When it has proved inconvenient or impossible to dissolve them for homogeneous liquid-scintillation counting, finely divided solid samples have been counted by suspending them in a liquid scintillator (*1*). With the aid of a gelling agent, settling of the suspension can be avoided. Aluminum and other metallic stearates give rigid gels when heated with toluene scintillator solution. Thixcin forms a thixotropic gel when thoroughly blended with scintillator, which permits ready application of internal-standard techniques.

We wish to report a new thixotropic suspending agent (*2*) that requires no heating or mechanical homogenization and does not decrease counting efficiency, even for low-energy tritium betas. Cab-O-Sil M-5,* at 3–5% concentration, forms a very satisfactory, almost transparent gel with toluene and

* A preparation of pure silica of extremely small particle size; G. L. Cabot, Inc., Boston, Mass.

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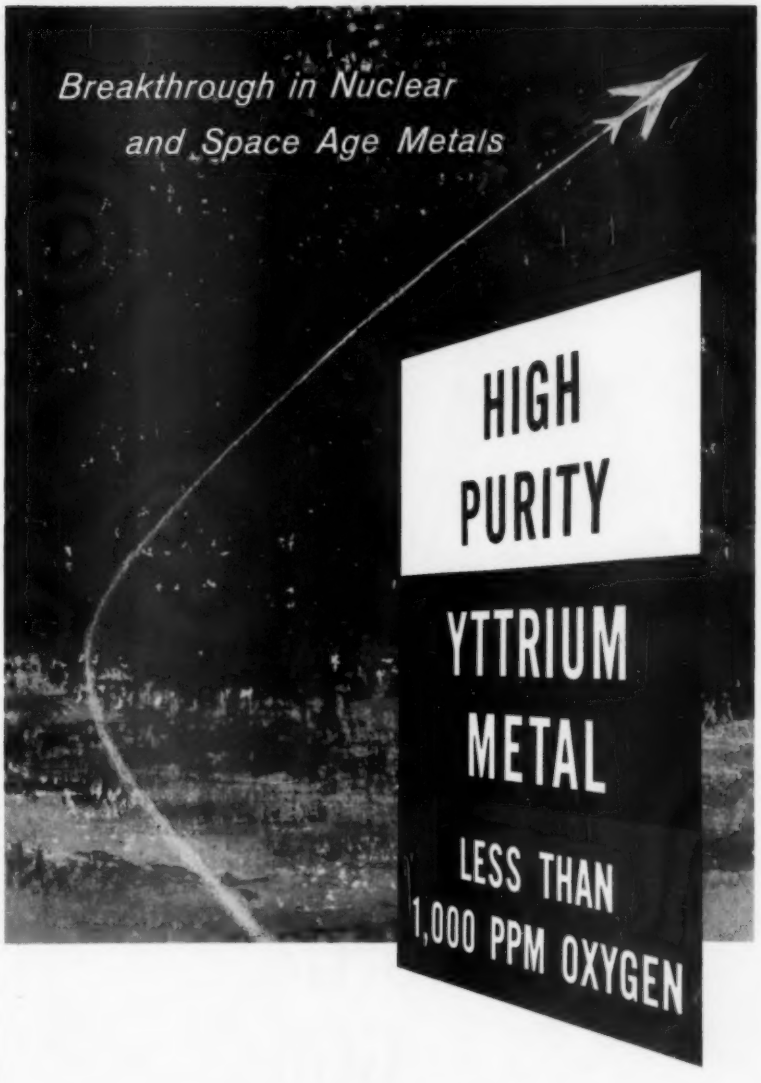

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This article starts on page 106

with aqueous (~5%) dioxane scintillator solutions.

The gels can hold at least 2 gm of heavy solids, e.g., lead chloride or barium carbonate, in a 20-ml volume. It is interesting to note that the counting efficiency for carbon-14 of a gel containing 2 gm of barium carbonate is ~85% that of the scintillator without added solid. Bone ash (10 gm in 20 cm^3 total volume) is also satisfactorily held in suspension and gives essentially the same counting efficiency for strontium-89 that is obtained with the viscous solvent system, 25% polystyrene in toluene, that has been in use for suspending bone.

With less than about 3% Cab-O-Sil, the suspensions tend to settle. The gel is quite thick at 5% concentration, although it can still be freed from trapped air bubbles by gentle shaking. Since counting efficiency and suspending capability are relatively independent of concentration (at least for 3–5% Cab-O-Sil), it has been found convenient merely to fill the counting bottle with Cab-O-Sil and add the liquid scintillator. For example, a 10-dram vial almost filled with Cab-O-Sil (bulk density about 0.03 gm/cm^3) gives a concentration of about 4% with 25 ml of solution.

BIBLIOGRAPHY

1. S. Helf, in "Liquid Scintillation Counting," C. Bell, F. N. Hayes, eds., p. 96 (Pergamon Press, New York, 1958)
2. Reported at the Associated Midwest Universities Conference on Radioactive Isotopes in Agriculture, Stillwater, Oklahoma, April 3 1959

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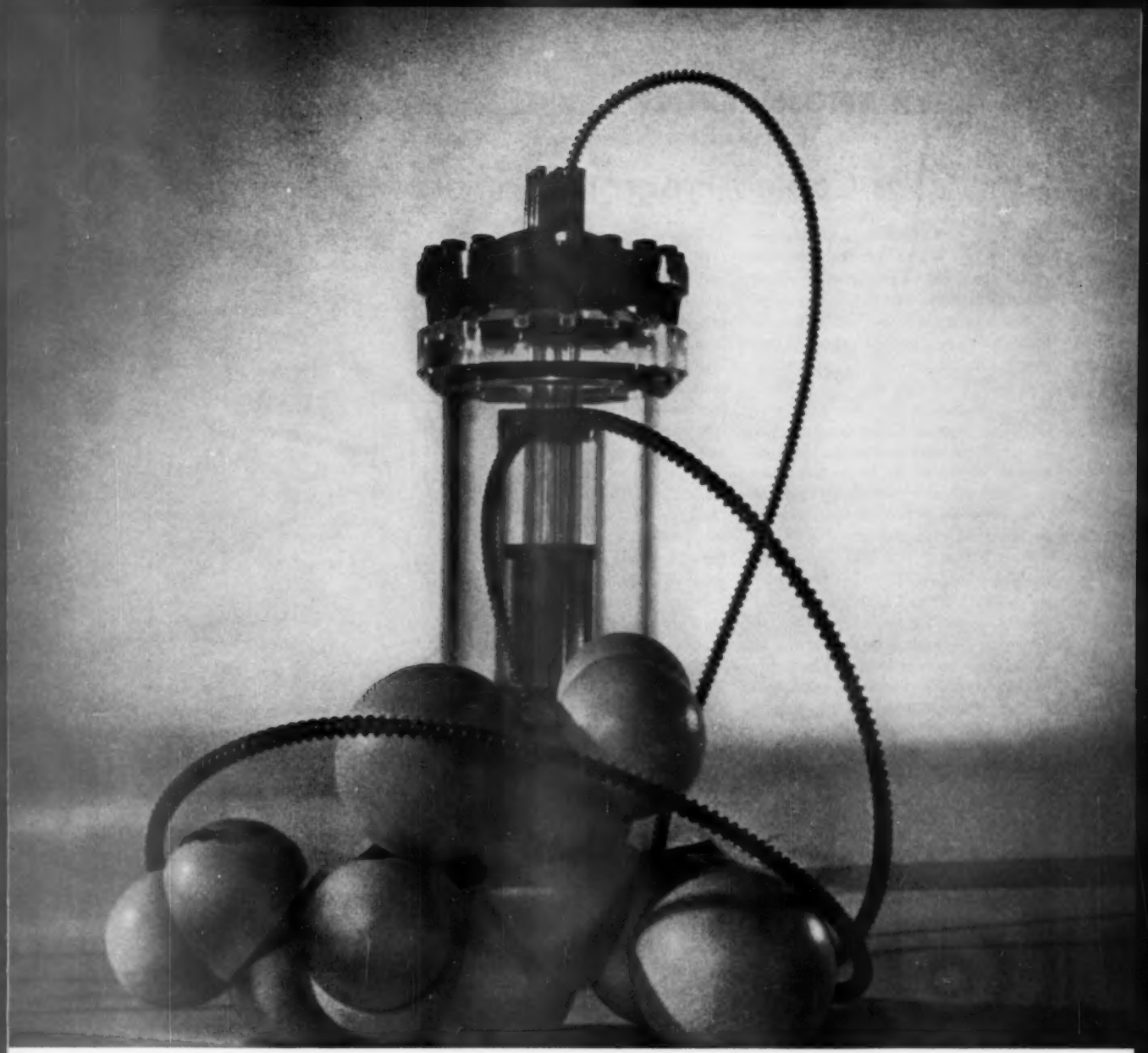

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Army Gas-Cooled Program Gathers Momentum

The program to develop a mobile gas-cooled power reactor for the Army involves at least three reactors now either in the construction or the design stage.

The first is the Gas-Cooled Reactor Experiment I, a water-moderated heterogeneous reactor (NU, Feb. '59, 52) that will be used to test various kinds of fuel elements for the program. GCRE-I is now under construction; Aerojet-General Nucleonics, the contractor for the whole Army gas-cooled program, recently reported* that the plate-type elements for this reactor are practically all fabricated.

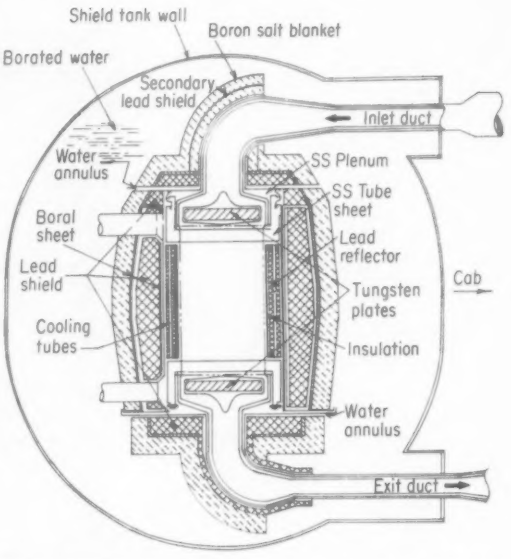
Next in line is GCRE-II, a graphite-moderated homogeneous reactor, which is described as "an advanced back-up" reactor system for GCRE-I. Preliminary core design is now in progress for this reactor, fuel-loaded graphite bodies have been obtained for tests, and a fuel-element thermal-cycle test designed.

The third reactor in the program is the ML-I (Mobile, Low-Power Reactor). This will be a prototype mobile power-generating unit scheduled to start construction by January 1961. The preliminary hazards report for this reactor (for operation at National Reactor Testing Station) has been completed and specifications issued for the turbine-compressor set and nuclear instrumentation.

Fuel design. Prospective fuel-element designs for the ML-I are already being fabricated for tests in GCRE-I. These include a plate-type element (the IA) and a pin-type element (the IB). Both smooth pins and finned pins are being considered. UN-stainless steel and UO_2 pellets are mentioned as fuel materials and stainless steel (for the IA) and nickel-base alloys (for the IB) as cladding materials. The ML-I fuel-element designs call for a hot-spot temperature of 1,650° F; the proposed materials are being tested in the MTR at temperatures in this range.

Mobile prototype. The ML-I will be mounted on two sets of skids—one for the reactor and one for the power-generator complex. The reactor will generate enough heat to power a 60-cycle, 400-kw generator, which means a power level of ~1.5 Mw(th).

Because the reactor is to be mobile, a large effort is being devoted to producing a minimum-size shield. The preliminary design (see figure) would give a total reactor package weight of 18 tons. With the reactor at full power, the dose 500 ft away would be 5 mr/hr. The water in the shield-tank would be drained when the reactor is to be transported (the reactor, of course, would be subcritical at such times). With the reactor loaded on a trailer truck, preferential shielding in the direction of the driver's cab would reduce the dose received by the driver from afterheat gammas to below 5 mr/hr (24 hr after shutdown).



SHIELD DESIGN for ML-1 keeps reactor weight <18 tons

* Army Gas-Cooled Reactor Systems Program, Monthly Progress Report, April 1959.

HTRE-1 Survives Damage Experiment

The Heat Transfer Reactor Experiment-1 (land-based version of a direct-cycle aircraft reactor at the General Electric Aircraft Nuclear Propulsion Department's Idaho Test Station) has survived without incident an experiment in which the reactor ran at full power with the air-coolant flow deliberately blocked in one fuel-element channel.* The objectives of the test were to (a) see what would happen to the reactor and (b) check the dispersion of fission products in the environment.

Molten portions of the fuel element left the core about ten seconds after the air was blocked by a special valve. This loss in reactivity caused a drop in power level which triggered compensating responses from the automatic control system. Five seconds later, or 15 sec after the valve was closed, the experiment came to an unexpected end when delayed neutrons from fission products passing through the outlet torus caused a period monitor to scram the reactor.

Although the reactor was at power with the valve closed for a total of only 15 seconds, the damage to the test element was extensive, approaching the limit predicted by thermodynamic studies. Inspection revealed no damage to any other part of the core.

Sampling and monitoring stations in the direction of the exhausted fission products checked the level of I^{131} to determine the pattern of dispersion. The observed values indicated a dilution greater by an order of magnitude than that predicted by Sutton's atmospheric diffusion equations. Radiochemical analyses found that in the most heavily oxidized parts of the element as much as 80% of the I^{131} had been released. Before the test, a special schedule of reactor operation had been followed to increase the ratio of I^{131} to gross iodine isotopes; this served to reduce the total activity released for a given level of I^{131}.

* R. E. Baker, C. C. Gamertsfelder and R. F. Gentzler, paper presented before the American Nuclear Society, June 1959.

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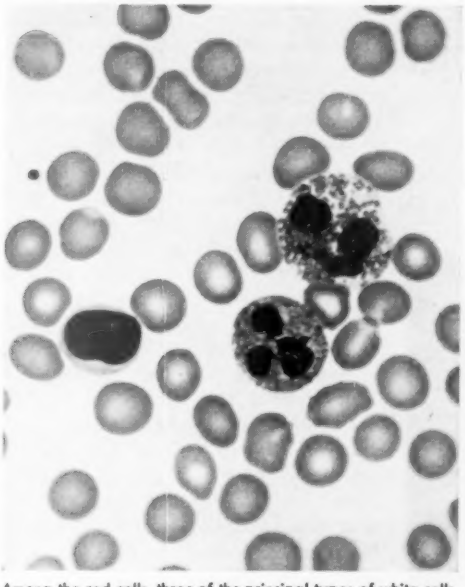
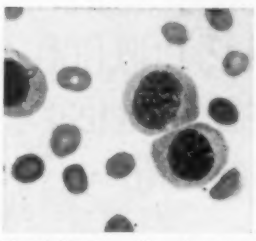
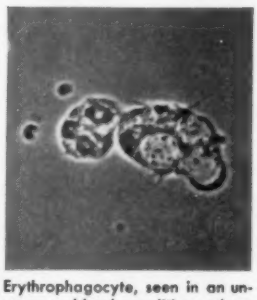
The sanguinary details



Among the red cells, three of the principal types of white cells, left to right:, a lymphocyte, representing about 30% of the white cells; a neutrophil, representing 60%; an eosinophil, representing about 2%.



Megaloblastic cells, characteristic of the pattern of red cell maturation in pernicious anemia.

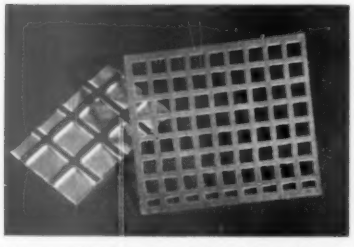


Erythrophagocyte, seen in an uncommon blood condition, where white cells swallow red cells. Here is one that has eaten three.

The objective documentation of hematological observations through properly controlled photomicrography is treated with some depth in the current issue of our periodical *Medical Radiography and Photography*. It contains some excellent color photomicrographs, including a series which depicts the maturation of human blood cells. However, if we were to go to the expense of reproducing the color on this page, it would use up money better spent in face-to-face instruction in hematological photomicrography for those who need it. You can look at the color all you want to by requesting a copy of the blood issue of *M. R. & P.* from Eastman Kodak Company, Medical Sales Division, Rochester 4, N. Y.

More film may be expended on Old Faithful in Yellowstone National Park than on all the blood in the world. Every man has his own idea of a natural marvel to photograph.

Photo-milling



New methods of metalworking do not come along often enough to be ignored. Here are two examples of what we call "photo-milling." The one on the right could, of course, have been done on a punch press if die cost had been justifiable. No die was used, nor were the openings cut individually. The one on the left looks like a milling machine job, for sure. It isn't.

This sort of thing is now best done photographically with a new light-sensitive preparation called *Kodak Metal-Etch Resist*. You spray it on, or dip, and dry. Then you expose to bright light under a film on which you have photographed the pattern. After a simple development, a flush that washes away the resist where the pattern kept the light off, and a bit of baking to remove the developer solvent, the metal is ready for whatever chemical or electrolytic etching works best. The resist protects from etching action vigorous enough to remove a quarter-inch of aluminum and considerable depths of stainless steel, tool steel, magnesium, titanium, and possibly some metals we know nothing about. To get the benefit of our thinking on the subject, write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

Photoelasticity by the slice

Westinghouse, long known as a hotbed of photoelastic activity, has been nice enough to cast upon the waters of industrial co-prosperity a piece of technique that could help sell more *Kodak Contour Projectors*. No time must be lost in spreading the word. Too long have we touted photoelastic stress analysis with no brighter prospect of gainful return than seeing a little film put to good use in recording the pretty patterns.

Westinghouse took one of these projectors of ours, a non-photographic optical-mechanical device intended for the checking of dimensions on enlarged images of mechanical parts, and they turned it into a magnifying polariscope. This they did in the interest of reaching reasonable decisions on the mechanical design details to enable a nuclear reactor pressure vessel to withstand the titanic stresses that it must bear.

Scale models were built out of a certain transparent epoxy resin which not only exhibits the well known differential retardation between light polarized parallel and perpendicular to the stresses, but can retain the effect "frozen in" after the pressure is released and the model is literally sliced up in various planes of interest to the stress analysts. Instead of yielding average values of stress over the areas where electrical resistance strain gages happen to be bonded, this method shows how the stress pattern builds up to ominous levels at points suspected or not. The *Kodak Contour Projector* is what brings the stress analyst in close, past the gross structure of the pattern, to the all-important fine details where structural failure starts.

Don't bother Westinghouse for a description of the optical, mechanical, and electrical additions they've made to the projector. It's enough that they are publishing a full description of the analytical method (Proceedings of the Society for Experimental Stress Analysis, *17*, No. 1). *They're not interested in selling projectors. Eastman Kodak Company, Special Products Division, Rochester 4, N. Y., is.*

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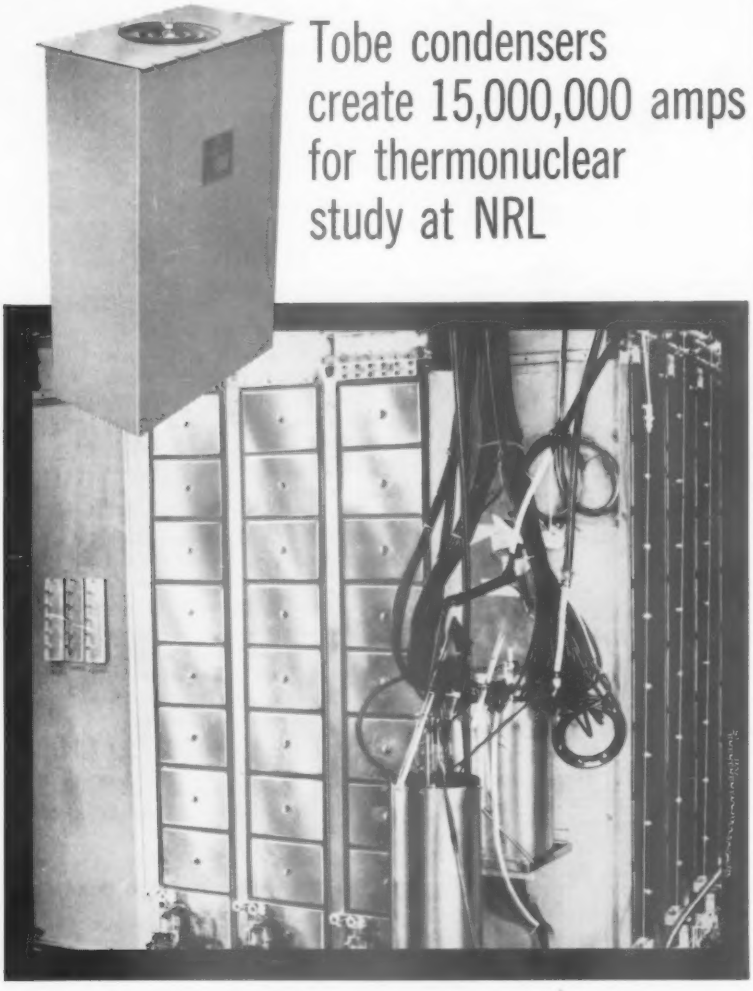

Tobe condensers create 15,000,000 amps for thermonuclear study at NRL

This Tobe condenser bank has a short-circuit current of 15 million amperes and a rise time of 2.8 microseconds. It is adding momentum to experiments by A. C. Kolb on high-velocity shock waves in thermonuclear devices at the U. S. Naval Research Laboratories.

The 99 Tobe condensers shown—totaling 1,430 uf—store 285,000 joules at 20 kv, and create discharge currents of 7-10 million amperes into an external inductance of about 0.01 uh.

Tobe's work for the NRL is another page in the rapidly expanding catalog of thermonuclear devices for which Tobe has supplied condensers. The same *creative engineering in action* is yours to command whether for energy-storage condensers, pulse-forming networks, or any high-power condenser application.

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NUCLEAR ENGINEERING

This article starts on page 110

Argonne Evaluates Process-Steam Reactors

For the last five months, Argonne National Laboratory (with the help of the architect-engineering firm of Sargent and Lundy) has been studying what sort of process-heat reactors might be developed from the pressurized-water, organic-moderated and boiling-water reactor concepts. In its summary report (ANL 6009) ANL sets forth an estimated range of steam costs for each concept and recommends reactor materials and fuel-element types.

The reference design was a 40-Mw system producing 125,000 lb of 380° F saturated steam per hour. Although ANL concludes that none of the three reactor concepts turns out to have a clear-cut advantage over the other two, it feels that with all things considered the PWR system looks somewhat better than the OMR and BWR. The steam-cost ranges for the reactors are:

Reactor	*¢/1,000 lb of steam*
PWR	64–150¢
BWR	83–172¢
OMR	75–154¢

Although the PWR shows the lowest costs, the relative differences are not considered significant; ANL favors PWR rather because its strong temperature coefficient makes for easy load control, its core characteristics are superior and it shows more potential for development.

The water-cooled concepts would have carbon-steel primary systems and zirconium-clad fuel; the OMR system would be of stainless steel with aluminum clad elements. ANL feels that the reluctance to use carbon steel in reactors so far is tied to the attitude that stainless steel has been demonstrated to work and does not cost "much" more. The report observes, "A process-steam reactor . . . is an excellent place to prove out carbon or low alloy steels without seriously affecting the system operability."

Scanning the Literature

Na and Bi liquid-metal-fuel systems. A literature search to June 30, 1957 on sodium, NaK and bismuth systems reviews the corrosion information for each liquid metal, discusses construction materials and fabrication of components and reports on tests of fuel

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NUCLEAR ENGINEERING

This article starts on page 110

concepts compatible with the metal. The bibliography lists 142 references. (ANL-5933; $1.50*)

Fission. A bibliography on fission from 1952 to September 1958. Contains 1,012 references listed alphabetically by author. (LAMS-2302; $3.50*)

Transfer functions of heat-exchangers. Transfer functions for various models of heat exchangers that are applicable to nuclear reactors are derived. Also, two heat-transfer processes are presented that can be used to describe the transient heat transfer in a distributed reactor core. (IDO-16486; $0.75*)

ANP heat transfer. A source file of heat-transfer data for design problems in aircraft nuclear propulsion. Turbulent flow of gases in various types of ducts is considered under the following aspects: heat flux and mode of heat-input effects, entrance-region effects, duct-cross-section effects, annular passages and heat-transfer–momentum analogies. (APEX 425; $2.00*)

Neutron cross sections. A neutron transport equation that was solved numerically (the SNG code by B. Carlson) has been connected with multigroup neutron cross sections and critical assemblies to display the area of coverage (fast to epithermal reactors) and range of errors ($\Delta k \simeq \pm 1\%$). (LAMS-2255; $3.00*)

Instrumentation for Atomic Medicine reviews techniques and diagnostic applications used in *in vitro* and *in vivo* measurements. 103 pp. $2.50. *Baird-Atomic, Inc., 33 University Rd., Cambridge, Mass.*

NBS handbooks. Protection Against Neutron Radiation up to 30 Mev (Handbook 63, 40¢); Design of Free-Air Ionization Chambers (Handbook 64, 20¢); Safe Handling of Bodies Containing Radioactive Isotopes (Handbook 65, 15¢); Safe Design and Use of Industrial Beta-Ray Sources (Handbook 66, 20¢). *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

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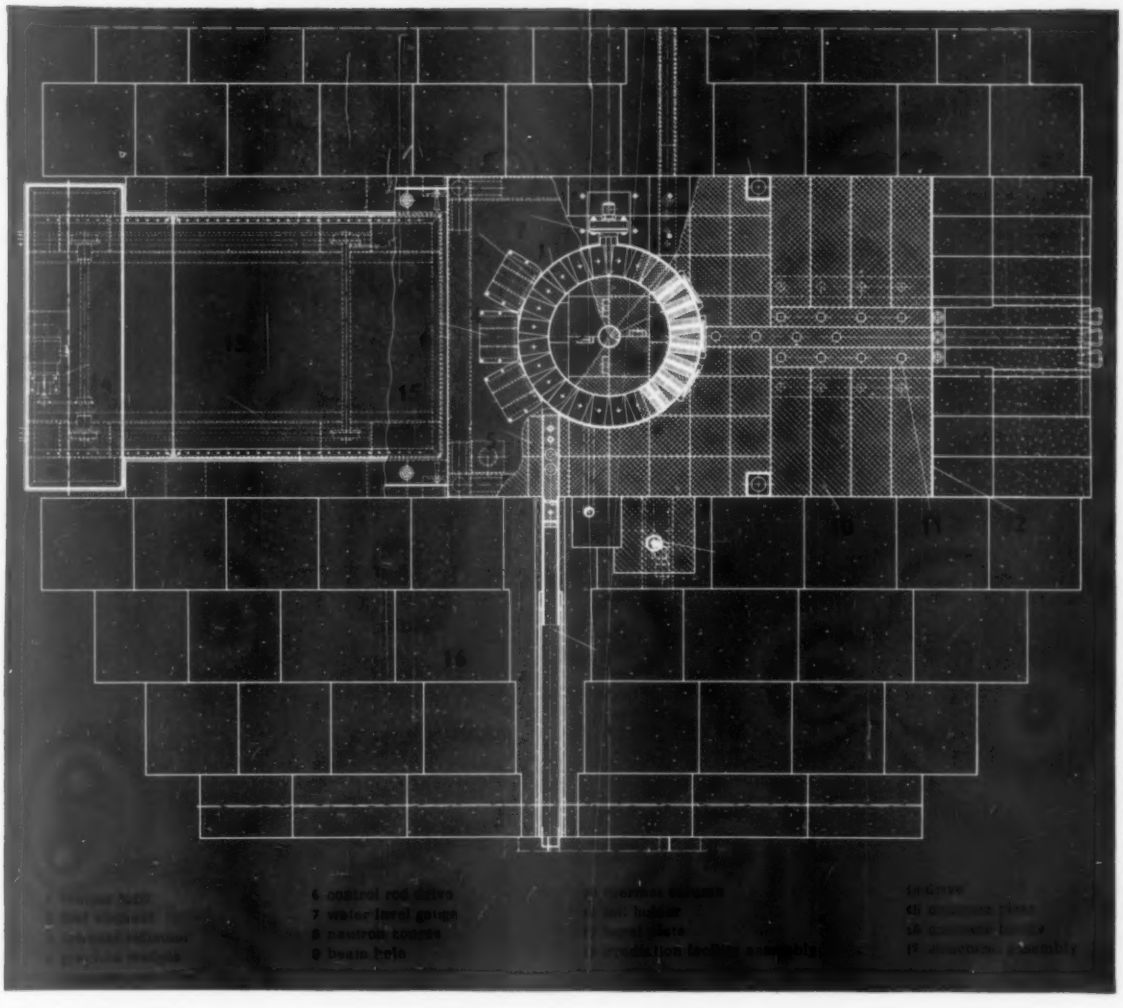
* Available from the Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.



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AMP—Effective Ion Exchanger for Treating Fission Waste

By J. VAN R. SMIT, W. ROBB and J. J. JACOBS
National Chemical Research Laboratory
South African Council for Scientific and Industrial Research
Pretoria, South Africa

Synthetic organic ion exchangers are very susceptible to radiation damage and therefore are unsuitable for processing highly radioactive solutions. Thus, in recent years, much attention has been given to the development of synthetic inorganic ion exchangers (*1–3*). Among the more promising of these is ammonium molybdophosphate (AMP).

It has been known for over fifty years that the ammonium ions in AMP are reversibly exchangeable with alkali ions (*4, 5*), but it has only recently been realized that they can be used for chromatographically separating ions on columns of AMP (*6*). The selectivity of this ion exchanger for the alkali metals was shown to be greatly superior to that of conventional organic resins, e.g., with separation factors more than ten times as high as those of Dowex 50.

In acid medium, only monovalent ions that form insoluble molybdophosphates, viz., NH_4^+, K^+, Rb^+, Cs^+, Tl^+, Ag^+ and Hg^+, exchange significantly. The exchange is rapid and obeys the mass-action law. The adsorbability of these ions is usually little affected by the presence in solution of large quantities of nonexchangeable or weakly exchangeable ions. For instance, in 0.1 *N* ammonium nitrate solution, the distribution coefficient of Cs with AMP is about 6,000, while, in undiluted sea water of *p*H ~1, the distribution coefficient is still about 1,500.

In neutral medium, multivalent ions also exchange, apparently being adsorbed as basic monovalent ions, such as $Sr(OH)^+$, $Ba(OH)^+$, $Y(OH)_2^+$, etc., according to the mechanism (taking Ba^{++} as an example)

$$Ba^{++} + H_2O \rightleftharpoons Ba(OH)^+ + H^+ \quad (1)$$

$$Ba(OH)^+ + RNH_4 \rightleftharpoons RBa(OH) + NH_4^+ \quad (2)$$

where R represents the anionic molybdophosphate framework.* Reaction (1) is the *hydrolysis reaction* and (2) the *ion-exchange reaction*. Although this hydroxide complex of barium is normally relatively unstable in neutral solutions (*p*H 3–6), it is apparently stabilized relative to other species of the metal ion present in the system by adsorption on AMP. These monovalent hydrolyzed ions, especially those of trivalent metals, therefore have high intrinsic adsorbabilities. As an example can be cited a distribution coefficient of about 5,300 for tracer yttrium in 0.1 *N* ammonium nitrate at a *p*H of 3.5.

If macro quantities of the multivalent ions are adsorbed by this mechanism, it can be expected that sufficient hydrogen ions will be generated to lower the *p*H of the solution to a point where the hydrolysis reaction can no longer proceed. This is supported by experimental evidence (*1*).

The hydrogen ions formed by reaction (1) of the exchange mechanism can be satisfactorily neutralized by employing a suitable buffer solution, such as sodium acetate, thus enabling the hydrolysis reaction to proceed quantitatively to the right. Under these conditions, macro quantities of a bivalent ion (e.g., Sr^{++}) and a trivalent ion (e.g., Y^{+3}) can be easily separated on a comparatively small column of AMP. The bivalent ion can be eluted with a moderately concentrated solution of an ammonium salt, but, for the rapid elution of the trivalent ion, an elutriant of *p*H < 1 is required (*7*).

* A more detailed account of the ion exchange on AMP of multivalent ions is now in preparation.

Use of Large AMP Columns

AMP normally precipitates as very fine crystals. Column beds of this

Advantages and Disadvantages of AMP

Advantages

1. Being an inorganic ion exchanger, AMP (ammonium molybdophosphate) should be resistant to radiation damage
2. "Saturation" capacity for cesium is comparable to that of organic resins and higher than that of most inorganic zeolites
3. "Breakthrough" capacity for cesium is considerably higher than for other organic and inorganic ion exchangers
4. AMP can be successfully used for separating bivalent and trivalent fission products if the feed solution is neutral
5. Since the exchange is completely reversible, AMP can be reused repeatedly
6. AMP can be dissolved in dilute alkaline solution and reclaimed by acidifying—a possible method for recovering Cs^{137} after the adsorption cycle
7. Since AMP adsorbs Cs^{137} efficiently from even fairly concentrated nitric acid solutions, Cs^{137} could be recovered from fission-product solutions without prior deacidification, as is necessary with other ion exchangers
8. Since AMP can quantitatively remove Cs^{137}—the longest-lived γ-activity—the problem of storing and shielding fission-product waste would be considerably reduced
9. AMP is comparatively cheap, readily available and easily prepared

Disadvantages

1. AMP has a finite solubility in aqueous solutions and peptizes slowly in pure water; this is minimized by keeping it in contact with a dilute aqueous solution, preferably one containing ammonium ions
2. Since AMP alone is impervious to liquids, asbestos must be added to provide porosity

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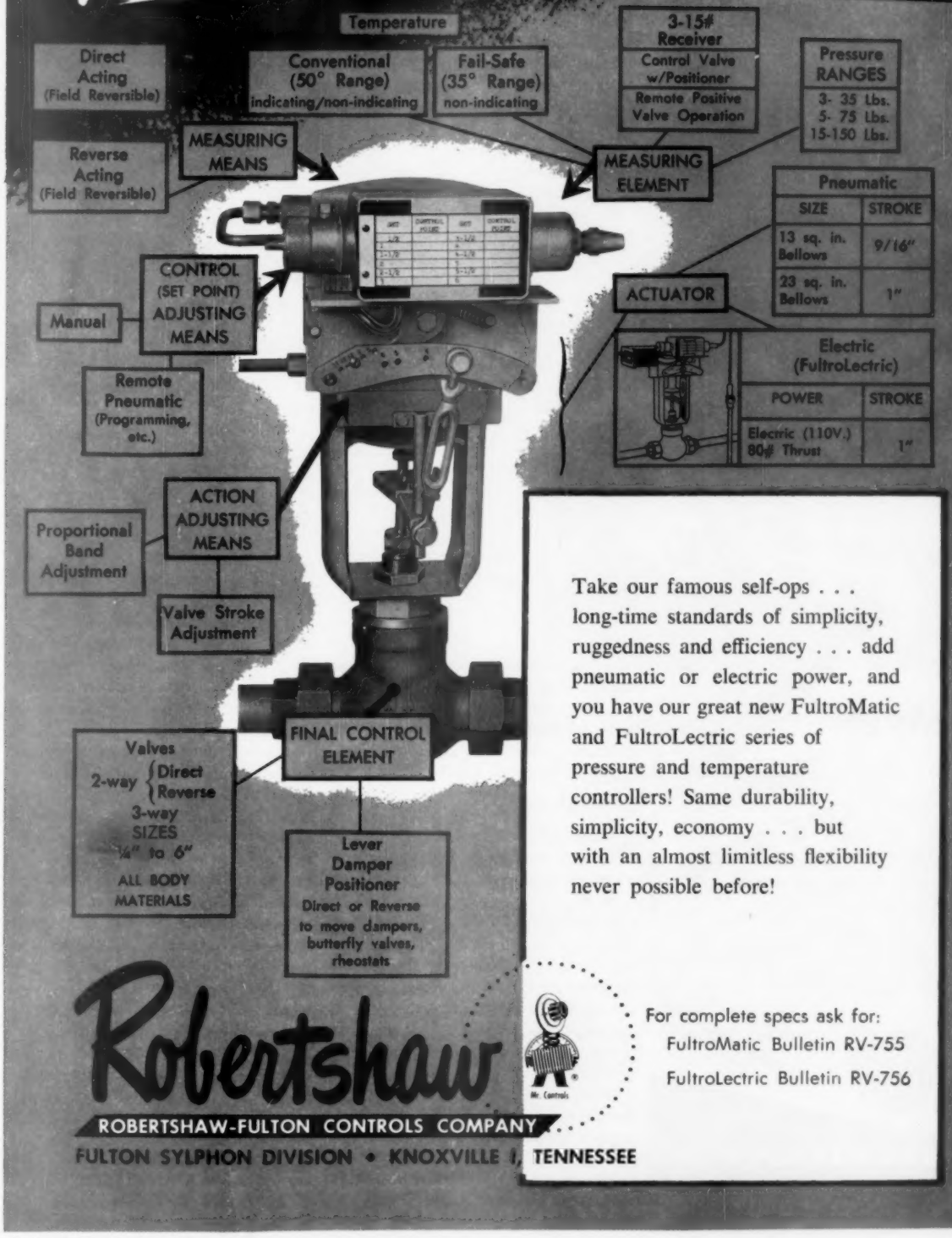

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material would be impervious to fluids.

This problem is easily overcome by mixing AMP with asbestos fiber (*7*). When mixed in water or a dilute electrolyte solution, the AMP crystals appear to adhere firmly to the asbestos fibers. After settling, the mixture shows no tendency to separate, and a favorable rate of flow in large columns can be achieved.

Acidic FP Solutions

In our experiments with acidic fission-product solutions, we used solutions of mixed fission products in dilute nitric acid as supplied by the Radiochemical Centre, Amersham.

A mixture of 0.25 gm each of AMP and asbestos was packed in a polyethylene column 0.61 $cm^2 \times 1.9$ cm. Three drops of a ~9-month-old fission-product solution were applied to the top of the column bed and eluted with various elutriants containing ammonium chloride or hydrochloric acid or both.

A large peak came off with the first few column volumes. After considerable washing, the activity remaining on the column was shown by its gamma-ray spectrum (Fig. 1) and aluminum absorption curve to be due principally to Cs^{137}. A long "tail" was observed following the first elution peak due to unadsorbed activities. The gamma spectrum of samples collected in this tail identified the activity as being due mainly to Zr^{95}-Nb^{95}.

These experiments clearly demonstrate the feasibility of separating Cs^{137} from fission-product solutions by means of ion exchange on AMP.

Zr^{95}-Nb^{95} Behavior

According to our hypothesis of the AMP ion exchange, Zr^{95} and Nb^{95}, when present in solution as cations, were not expected to remain adsorbed after treatment of the column with a strongly acidic elutriant. Their retention on the column can now be satisfactorily explained, however, in the light of recent information.

Carrier-free Zr^{95} and Nb^{95} are two of the most troublesome fission products and behave quite anomalously in aqueous solution, both in the recovery process for uranium and in the treatment of fission-product wastes. Bruce (*8*) reports that approximately two-thirds of the Zr-Nb activity in the uranium-solvent-extraction product is adsorbed on finely divided particulate

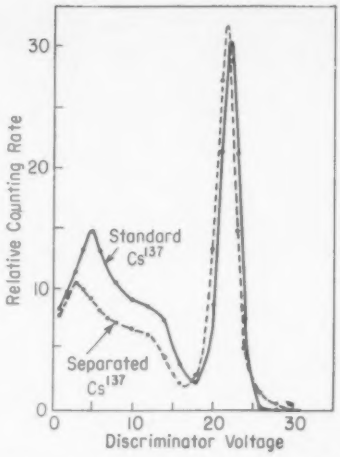


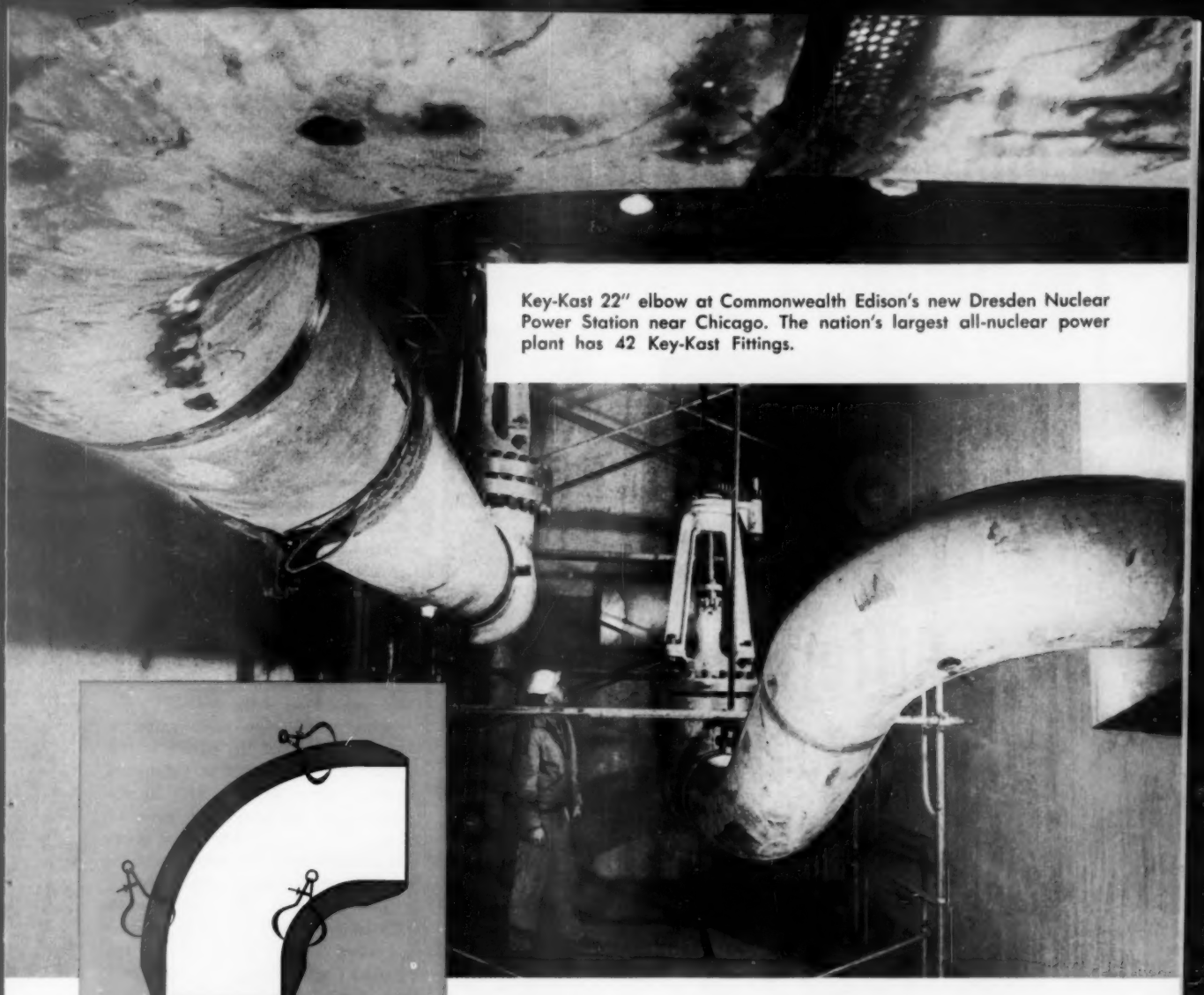
FIG. 1. GAMMA SPECTRA of standard Cs^{137} and of Cs^{137} separated from acid fission-product solution by AMP ion exchange

material that is present. He attributes an appreciable portion of the decontamination realized to the filtering action of the column bed on particulated matter.

Similar difficulties have also been experienced with columns of organic resins (*9*). Some of the finely divided solids containing the adsorbed activities and retained on the column during the sorption cycle slowly dissolved or peptized during both the washing and the elution cycles, thus contaminating the effluent.

Our observations are probably due to similar causes. The following experiment with separated carrier-free Zr^{95}-Nb^{95} in dilute oxalic acid (obtained from Oak Ridge National Laboratory) confirmed this view. The conditions in this experiment were similar to those in the column separation of the fission products in neutral solution (described later) to evaluate the adsorption behavior of this couple in neutral medium.

A 1:1 mixture of AMP-asbestos was packed to a depth of 3.6 cm in a polyethylene column of 0.61 cm^2 inside cross-sectional area. The bed was conditioned by passing through 1 *N* NH_4NO_3 followed by 0.01 *N* NH_4NO_3. One-half milliliter of 2% sodium acetate buffer solution of *p*H 4.5 was now transferred to the top of the column, followed in close succession by one drop of the Zr-Nb solution (in 0.66 *N* oxalic acid as received; ~75 μc per drop) and 0.5 ml of the same buffer solution. Elution was then carried out with 0.01 *N* NH_4NO_3, 1 *N* NH_4NO_3 and 1 *N* $NH_4NO_3 + 1$ *N* HNO_3. Fractions of five drops each



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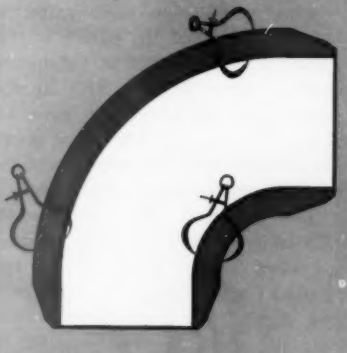

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were collected on aluminum planchets, dried and counted. A large portion of the activity passed through unretarded, but excessive tailing indicates that a portion of the activity was at least weakly adsorbed or retarded. Raising the ammonium nitrate concentration of the elutriant from 0.01 N to 1 N produced no significant peak, indicating the absence of moderately strongly held species analogous to that of Sr^{++} [adsorbed as $Sr(OH)^{+}$ under these conditions]. Upon further elution with 1 N NH_4NO_3 + 1 N HNO_3, a well-defined peak appeared in the effluent showing that a portion of the activity was probably strongly adsorbed as a hydrolyzed species, as with Y^{+3}, etc. Again a large tail to this peak was observed. Examination of the column bed, after elution had been discontinued, revealed that approximately half of the original activity remained on the column, most of it confined to the upper 0.5 cm of the bed.

Owing to the close resemblance in their half-lives and the nature of the radiations they emit, it is difficult to measure either Zr^{95} or Nb^{95} in the presence of the other, or even to demonstrate conclusively that a given sample has been enriched (as compared with the equilibrium mixture) in one of these nuclides. This applies especially to this experiment where mutual separation of Zr^{95} and Nb^{95} in the different fractions apparently has only been slight. We have therefore not tried to determine the behavior of individual members of this couple.

Neutral FP Solutions

In the light of the information available about the ion-exchange behavior on AMP of multivalent cations in neutral solutions, it seemed worthwhile to investigate the possibility of treating neutral fission-product solutions with columns of AMP.

In this investigation, we used the same fission-product solution that was used in the earlier experiments. It was now about 18 months old and should have contained only the following fission products in significant amounts (half-lives are given in parentheses): Sr (26 y), Cs (37 y), Ru (1 y), Zr-Nb (65 d), Tc (2×10^5 y), Sb (2.7 y), Ce (280 d), Pm (2.6 y), Y (61 d), Sm (73 y) and Eu (1.7 y). Some of these have short-lived daughters. The bulk of the Zr-Nb activity had probably decayed away, while the

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contribution to the total activity by technetium, owing to its very long half-life, was probably very small.

A 1:1 mixture of AMP-asbestos was packed into a polyethylene column to obtain a bed with dimensions 0.61 $cm^2 \times 5.0$ cm. After conditioning the column with 1 *N* and 0.01 *N* ammonium nitrate solution, successively, 0.5 ml of a 2% sodium acetate buffer (pH ±4.5) was added to the column, followed in close succession by one drop of fission-product solution (containing about 200 μc per drop in dilute nitric acid) and 0.5 ml of the buffer solution. The solution was allowed to seep in; elution was then carried out successively, with 0.01 *N* NH_4NO_3, 1 *N* NH_4NO_3 and 1 *N* $NH_4NO_3 + 1$ *N* HNO_3. Five-drop fractions of the effluent were collected on aluminum planchets and dried and counted with an end-window counter (efficiency about 10%) after allowing at least ½ hr after collection for decay of any separated short-lived Ba^{137}.

In the initial elution with 0.01 *N* NH_4NO_3, a large portion of the activity passed through unadsorbed. The γ-spectrum of the combined fractions of this activity peak showed spectral peaks at 510, 620, 750 and 1,040 kev (with intensities in this order). These γ-peaks (except the 750 kev) closely agree with the principal gammas of $(Ru^{106}\text{-})Rh^{106}$ given in the literature (513, 622 and 1,045 kev), indicating the presence of Ru^{106}. The 750-kev peak can possibly be attributed to Zr^{95}-Nb^{95} (730- and 750-kev γ-energies, respectively).

A small activity peak appeared after the first peak. The γ-spectrum of the small peak was very similar to that of the first peak. Since ruthenium in fission-product mixtures is known to exist in a number of complex ions and molecular species in each of these states (*10, 11*), the appearance of this small peak might be explained as being due to a Ru species that was weakly adsorbed on the AMP, while the rest of the Ru activity had not been adsorbed at all.

Elution of the column with 1 *N* NH_4NO_3 produced a large, well-defined peak, consisting mainly of Sr^{90}. The γ-spectrum showed no peaks, while the spectrometer reading over the entire range was less than 30% above background, showing the absence of γ-radiation. The counting rates of the different fractions of this peak were approximately doubled when re-examined a week later, indicating growth of the Y^{90} daughter and

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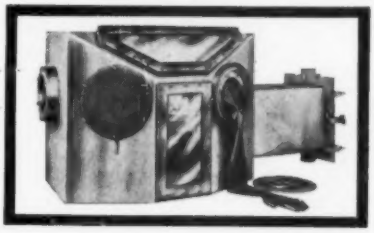

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further confirming the identity of the principal species eluted in this peak as Sr^{90}.

Further elution of the column with an acid ammonium nitrate elutriant (1 *N* NH_4NO_3 + 1 *N* HNO_3) produced another peak much larger in size than any of the earlier peaks. The total activity removed from the column with this elutriant probably represented more than half of the fission-product activity taken. γ-spectra indicated the presence of a high proportion of gammas of energy lower than 100 kev. Well-defined peaks were found at 135 and 700 kev, and a small peak at 1,480 kev. These figures correspond to γ-energies given in the literature for the Ce^{144}-Pr^{144} pair, to which the bulk of the rare earth γ-activity in an 18-month fission-product mixture is attributed.

Subsequent examination of the column showed that more than 80% of the residual activity was found in the top half of the column, with the lower one-tenth containing less than 1% of the total activity in the column. γ-spectra of the different sections showed that only an insignificant portion of the activity of this lower section was due to Cs^{137}.

The 2.7-yr Sb^{125} has not been identified in any of the fractions collected. A separate experiment, similar to the one described for Zr^{95}-Nb^{95}, was carried out with a trace amount of antimony (natural antimony activated in the Harwell pile) in a solution containing some chloride ions and acetate buffer of *p*H 4.5. Most of the antimony passed through unadsorbed or was only weakly held. The column was eluted with the same elutriants as in the Zr-Nb experiment. Excessive tailing followed the appearance of the first peak due to unadsorbed antimony. No significant increase in the effluent activity resulted when the ammonium nitrate concentration of the elutriant was raised from 0.01 *N* to 1.0 *N*. A peak, representing about one-fifth of the activity taken, was produced when the column was finally eluted with 1 *N* HNO_3 + 1 *N* NH_4NO_3. At the end of the experiment, only a negligible portion of the activity was left on the column.

As the Sb activity in this experiment was associated with a small amount of isotopic carrier, the behavior of carrier-free Sb^{125} in fission-product solutions may follow a different pattern. Further investigations are required before any valid conclusions about the latter can be safely drawn.

A separation similar to the one described above has been carried out on a fresher fission-product solution about 6–8 months old. The AMP-asbestos column had dimensions 0.61 $cm^2 \times 5.0$ cm. One drop of fission-product solution was used together with 1.0 ml of sodium acetate buffer, *p*H 4.0, as described previously; 0.1 *N* LiCl solution has been used instead of 0.01 *N* NH_4NO_3 as the initial elutriant in an effort to improve resolution of the second small ruthenium peak. However, with this elutriant only a very small peak was ob-

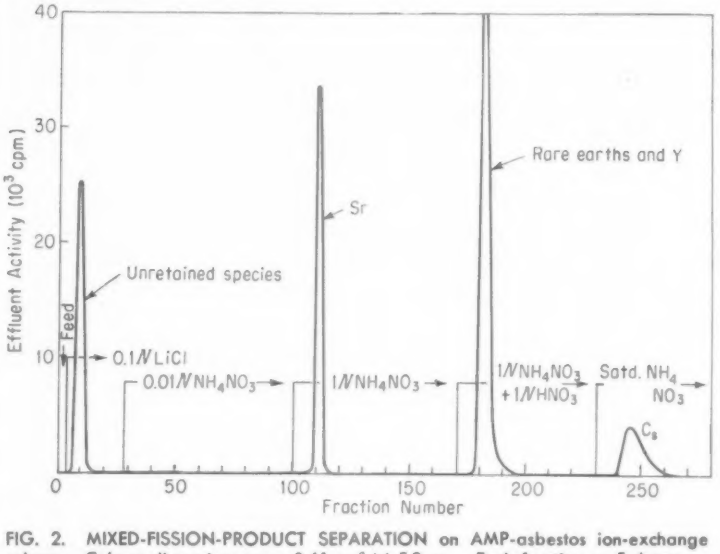

FIG. 2. MIXED-FISSION-PRODUCT SEPARATION on AMP-asbestos ion-exchange column. Column dimensions were 0.61 $cm^2 \times 5.0$ cm. Each fraction = 5 drops

served. All the samples were counted on the lowest shelf of the lead castle (i.e., with an efficiency of ±2%). The elution curve, shown in Fig. 2, gives a good indication of the completeness of separation and of the relative amounts of activity eluted in the various peaks. Each peak was again analyzed γ-spectrophotometrically with results similar to that of the experiment with the older fission-product solution. The final peak contained at least 98% Cs^{137}, with Zr^{95}-Nb^{95} as a contaminant. Only a very small amount of activity remained on the column after completion of the experiment.

Resistance to Radiation

As with other inorganic ion exchangers, AMP should be resistant to high radiation doses. Small samples of AMP have been irradiated for one week in the core of the BEPO pile at Harwell. Photochemical reduction of the AMP was the only likely radiation damage anticipated, and this occurred only to a very small extent with the sample mixed with a small quantity of water. However, a dry sample and samples wetted with 2 *N* nitric acid and 2 *N* hydrochloric acid showed no sign of reduction to the blue compound.

The ion-exchange properties of these samples were not examined afterward. However, since the ion exchange of AMP results from its crystal structure, and since the latter is not expected to be significantly affected by radiation, especially if the AMP remains in contact with an aqueous solution, we anticipate that the ion exchange of AMP will not be seriously affected by high doses of radiation. Further experimental evidence is required to substantiate this surmise.

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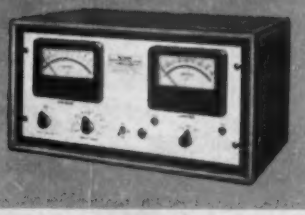

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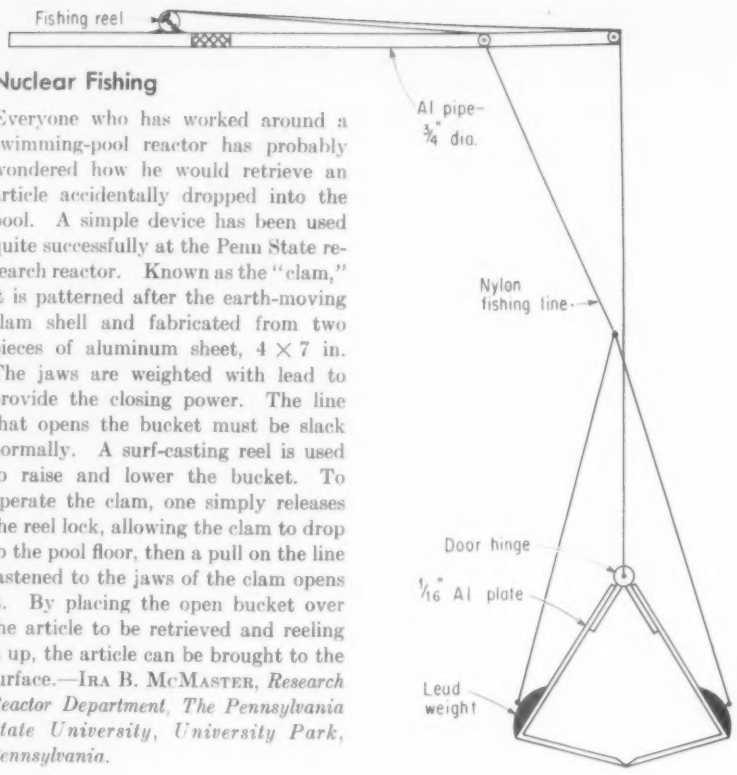

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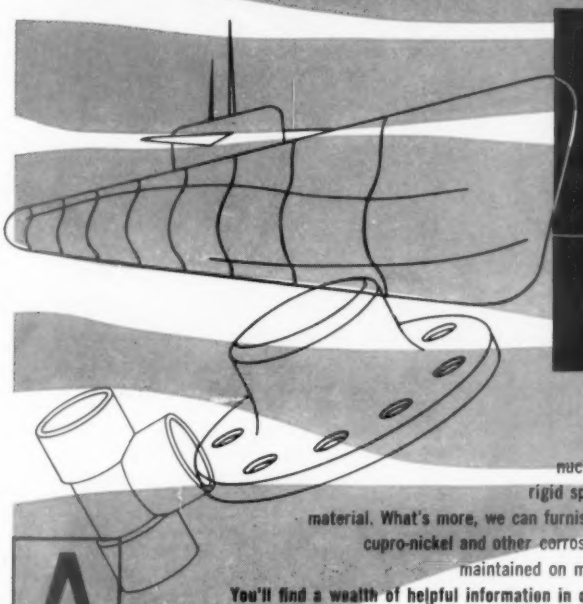

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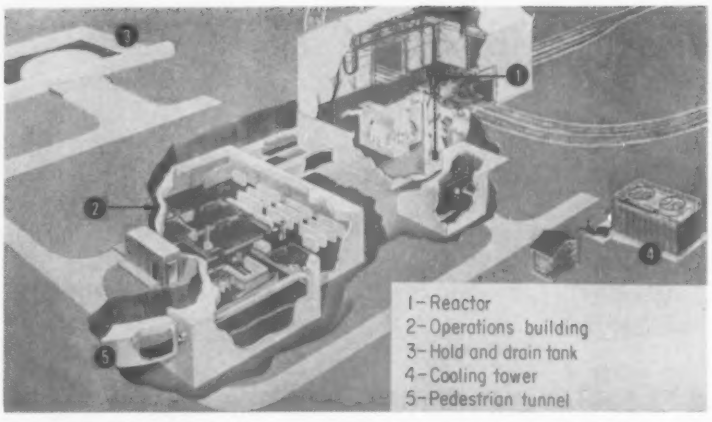

FIG. 1. IRRADIATION FACILITY. Systems to be irradiated are carried into reactor building on flat cars. Since reactor is above ground and air-shielded during operation, operations building is underground

Georgia Reactor—New Facility for Dynamic Irradiation Testing

By A. M. LIEBSCHUTZ and M. M. MILLER
Lockheed Nuclear Products, Lockheed Aircraft Corporation
Georgia Division, Marietta, Georgia

A new testing-reactor facility has risen near Dawsonville, Georgia—the Georgia Nuclear Laboratories. The facility is unique in that it permits the dynamic testing of full-scale components and systems under conditions comparable to those expected in an operating nuclear aircraft.

The research center is officially designated the Air Force Plant No. 67 and it is operated for the Air Force by Lockheed Aircraft Corp. Architect-engineer for the facility was Vitro Engineering Corp., and the reactor designer and builder was General Electric.

A conventional testing reactor, such as the Materials Testing Reactor, can accommodate only small specimens—of the order of a cubic foot or less—in cavities in the reactor shield or moderator. During irradiations, the Georgia Nuclear Laboratories radiation-effects reactor (RER) is collimation-shielded. This provides about 16,500 ft^3 of irradiation volume and a frontal area of 720 ft^2.

Since the air-shielded operation of the reactor requires a large exclusion area, the site selected is a 10,000-acre area about 60 miles north of Atlanta. The nearest town is Gainesville, 22 miles away.

The GNL is composed of two major complexes—the Radiation Effects Facility (REF), where the reactor is located (Fig. 1), and the Nuclear Support Facility, where the Radiation Effects Laboratory (REL) and other support facilities are located. The

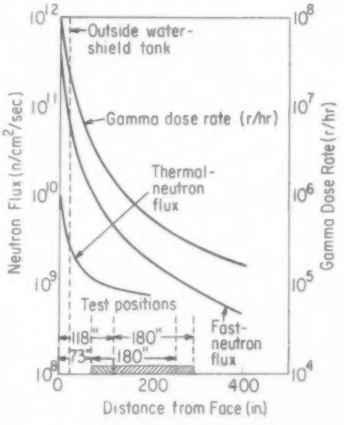

FIG. 2. REACTOR IRRADIATION FIELD with reactor operating at 10 Mw. Dimensions at bottom indicate available fluxes with flat cars in position for irradiation

REF and REL are connected by a standard-gage railroad for transporting the irradiation specimens.

The 10-Mw reactor is pressurized, heterogeneous and light-water cooled and uses fully enriched ETR-type elements. The core is designed to have a lifetime of 7,000 Mwh at rated power. Calculated neutron and gamma fluxes outside the reactor are given in Fig. 2. The reactor is housed in an aluminum building to minimize induced activity in the area.

For irradiations, test articles are moved into the reactor building on flat cars, and then the reactor is raised hydraulically from its pool. Refrigeration or heating equipment is placed behind a shield on the car and controlled from the operations building; hydraulic or pneumatic power is handled similarly. Power lines, control cables and instrumentation for the tests are routed from the operations building to stationary halves of mating connector boards in the reactor building, which connect them to corresponding boards on the test cars.

Surrounding the core are boral-clad tanks that can be remotely filled with water to modify the gamma-to-neutron ratios. Fast- and thermal-neutron attenuation by the shield tanks and the boral is calculated to be by a factor of 10^3.

The REL is primarily intended for evaluating the results of irradiation. Flat cars carrying the test specimens are taken directly into a disassembly hot cell; from there, components are transferred to test cells. The cell row is equipped to perform remotely all standard engineering tests.

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d/M-Gauge*, a portable instrument for field measurement of moisture content developed by the Nuclear-Chicago Corporation, employs a radium-beryllium fast neutron source by United States Radium Corporation, leader in design, development and production of a variety of neutron, beta and gamma radiation sources for industrial technology.

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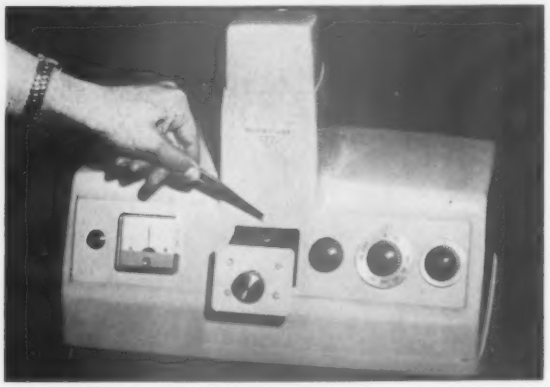


FIG. 1. READING DEVICE holds small glass dosimeter in chuck to expose it to exciting ultraviolet and measure fluorescence

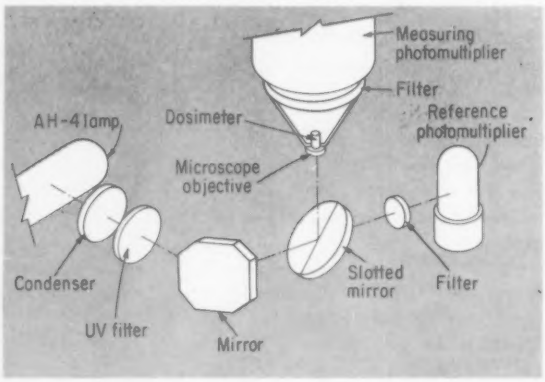


FIG. 2. INSIDE READER, optical system splits exciting beam to produce both reference signal and fluorescence signal

Commercial Microdosimeter Uses Glass Fluorescence

Small bits of glass rod and a unique fluorescence reader form a commercial dosimetry system designed for field mapping and therapy. Accuracy of 5% or better is available at 10–10,000 rads, and the system is capable of detecting 1 rad. Development has been by G. E. Blair, C. H. Brumley, R. J. Meltzer and J. L. Rood of Bausch and Lomb Optical Co., Rochester, N. Y.

The basis is radiophotoluminescence —creation of stable luminescent centers by the photochemical action of ionizing radiation. The dosimeter is of integrating type and permits reading individual and cumulative doses. Response is linear from 50 to 10,000 rads and flat for photon energies of 0.25–2 Mev. At energies below this range there is energy dependence.

The method is the one conceived by Schulman and his coworkers* at the Naval Research Laboratory. Silver-activated phosphate glass [50% $Al(PO_3)_3$, 25% $Ba(PO_3)_2$, 25% KPO_3 with 8% $AgPO_3$ added to this base] is drawn into 1-mm rod and cut into 6-mm lengths, and the ends are ground and polished.

Reading is done with the device of Fig. 1. The knob on the center drawer opens a three-section chuck, which closes by itself when the knob is released and holds the dosimeter in the reading position.

Figure 2 is a schematic representation of optical paths in the reader. Ultraviolet radiation peaking at 3,650 A is divided into two paths by a slotted mirror. Part goes to a reference photomultiplier; the rest excites the dosimeter. Fluorescent radiation from the dosimeter is collected by a conical reflector and directed through the orange-pass filter (excluding ultraviolet light) to an end-on photomultiplier tube.

Front-panel adjustments include a zero adjustment (for reference signal strength), a range switch (for measurement signal strength), and the measuring dial, which balances two triodes in a comparator with a microammeter between their plates.

Glass responses are shown in Fig. 3. After irradiation a day's storage at room temperature produces equilibrium, or equilibrium is achieved by heating at 130° C for 10 min.

There is also some variation with temperature during irradiation, storage and measurement, but it is small and predictable—for example +0.3%/° C during irradiation and −0.7%/° C during measurement.

* J. H. Schulman et al, NUCLEONICS **11**, No. 10, 52 (1953); J. H. Schulman, H. W. Etzel, *Science*, **118**, 184 (1953); J. H. Schulman et al, *J. Appl. Phys.* **22**, 1479 (1951).

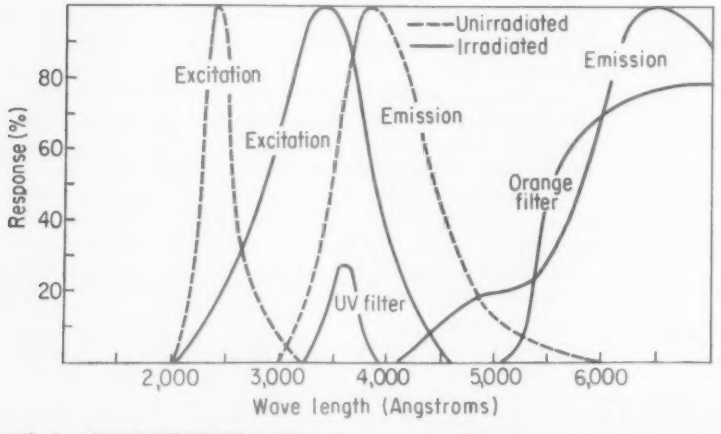


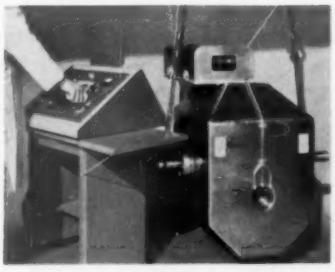
FIG. 3. GLASS RESPONSE produces long-wave-length fluorescence in response to ultraviolet excitation. Also shown are pass bands of filters used

Radiographers Use Kilocuries of Co^{60}

Radiography has advanced to kilocurie cobalt sources with the design of the two housings shown in the photographs. Figure 1 shows a Picker Cyclops capable of holding 1,500 curies of Co^{60}; Fig. 2 shows a Budd Nuclear Systems Multitron 1060 designed for up to 1,000 curies.

The Cyclops installation shown is at Cooper Alloy Corp., Hillside, N. J. Pump and valve castings for nuclear reactors are its principal targets. The unit is presently charged with ~625 curies of Co^{60} to produce an intensity of 600–700 rhm (roentgens/hr at 1 meter). Inspecting the valve casting shown in the figure requires a total of 82 exposures and 40 hr.

PICKER CYCLOPS at Cooper Alloy Corp. holds 625 curies of Co^{60} and is capable of holding up to 1,500 curies



BUDD'S MULTITRON 1060 will hold up to 1,000 curies of Co^{60}. Box on top of system

The Multitron 1060 weighs 5,000 lb and delivers a 30-deg cone of gamma rays with the source in position for use. Cadmium-sulfide detectors indicate the position of the source and transmit the information to lights on the control console. The box on top of the shielding housing contains a 12-volt d-c drive and its dry batteries. These automatically retract the source in a power failure.

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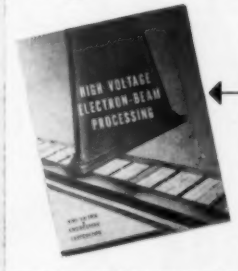

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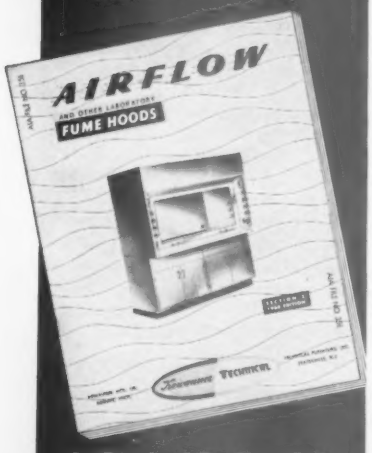

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Krypton in a Cage—Clathrate Beta Sources

By D. J. CHLECK and C. A. ZIEGLER
Tracerlab, Inc., Waltham, Massachusetts

Krypton-85 offers the advantage of useful 10.3-yr half-life and an uncomplicated beta emission. Its chemical inertness is both an advantage and a disadvantage. Since it does not combine, it does not enter a metabolic system and is very safe from a biological standpoint. At the same time, since it does not combine, it is hard to handle. Heavy cylinders that are usually used to store and compress the gas also suppress the beta particles from it.

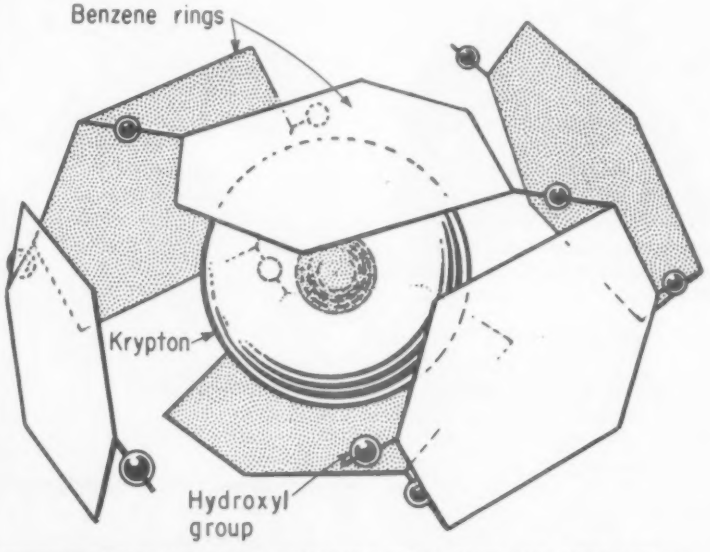
A new way of handling Kr^{85} overcomes the difficulty and provides a safe and useful source of beta radiation (*1*). It consists in trapping the krypton in a three-dimensional organic crystalline "cage" called a "clathrate." The resulting material is originally formed in lumps weighing 0.5–1 gm and having a specific gravity of ~1.5. Using krypton that is 5% Kr^{85}, one can obtain a specific activity of 3 curies/gm. The figure below illustrates the form of the krypton-filled cage.

For use as a beta source the clathrate can be powdered into grains the size of salt or sugar. Little of the radioactivity is lost in powdering. Moreover there is little leakage—a few parts per million per day.

Safety in using the material results from its solubility. In the event of a spill, water or ketones can be used to dissolve the organic crystal, thus permitting the inert krypton to escape harmlessly into the atmosphere. Dissolution of the clathrate can also be used to provide a controlled release of gaseous Kr^{85}. Similarly the vulnerability to chemical attack leads to using the krypton-laden clathrate as a detector of certain gases. On the other hand, a thin protective coating is enough to guard against attack by atmospheric moisture without preventing escape of the beta particles.

Making a Clathrate

Chemists use the word "clathrate" (from Greek *klethra*, Latin *clathri—lattice*) to describe a molecular cage within which a second substance is trapped. Hydroquinone clathrates were first developed in 1950 by Powell for use as sources of inert gas without expensive



HYDROQUINONE MOLECULES $[C_6H_4(OH)_2]$ FORM CAGE AND HOLD Kr^{85} atom when crystallized from a melt under pressure. Result is stable source of beta particles

heavy-walled cylinders (*2*). At that time compounds incorporating argon, krypton and xenon were made. Helium, neon and radon are thought to be too small or too large for successful trapping in the clathrate cage.

Hydroquinone clathrates are characterized by the general formula $(quinol)_3 \cdot X$. Here X represents a substance of suitable size which has completely filled all the cage vacancies. The requirements for formation of a clathrate are quite specific (*3*). Most important are:

1. An open crystal structure in the enclosing component. This requires directed linkages holding the molecule and crystal together with sufficient extension of these groups to provide both a rigid structure and a cavity large enough to be useful.

2. Small access holes to the cavity. This can result from disposition of these groups during crystal formation.

3. Ready availability of the component to be trapped during the closing of the cavity.

The first two requirements are characteristics of quinol. Ordinarily quinol exists in an alpha form. However, if it is crystallized in the presence of a sufficient concentration of an inert gas, a beta form is produced with molecules of suitable size to stabilize the cage. The third requirement governs the efficiency of the clathrating process, which is defined as the fraction of the available cages that are filled with krypton atoms. The maximum efficiency—100%—corresponds to one krypton atom per three quinone molecules.

Clathrating efficiency is controlled by two factors: (a) pressure of the inert gas and (b) time allowed for crystal growth.

Powell's original technique produces a powder or fine crystal by growth from a water solution. This is satisfactory for production of nonradioactive clathrates. On the other hand, there are practical difficulties involved in using this method for radioactive clathrates. The principal ones are filtration of radioactive material, separation of radioactive solution and contamination of the expensive radioactive gas with water vapor.

Our procedure resolves these difficulties. The technique is growth from a melt rather than from a water solution.

Procedure. We place a sample of quinol in a pressure vessel, eliminate atmospheric gases and fill the apparatus with carrier-free krypton con-

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This article starts on page 130

taining 5% Kr^{85}, the form commonly available from Oak Ridge. The quinol is heated to slightly above its melting point (185° C) and then slowly cooled over a long time. High gas pressure and controlled cooling to prevent rapid crystal formation fulfill the requirements that we stated for good clathrating. Our maximum clathrating efficiency is obtained at 60 atmospheres and a growth period of 72 hr. Clathrate compounds prepared by this method contain about 25% of the theoretical maximum of krypton.

The density of krypton is such as one would obtain at a pressure of 25.8 atm and a temperature of 15° C. With 5% Kr^{85} as much as 3 curies/gm are incorporated in a hard fused mass, a form that is preferable to powder or fine crystal because it is easier to handle and minimizes the dangers associated with radioactive dust.

The clathrates are remarkably stable. No appreciable effects of degradation due to the presence of internal radiation have been observed, and leakage from the cage is extremely small—a few parts per million per day. Even with high specific activity, leakage is so small that maximum allowable concentration in a small sealed room will not be reached for several months. The fact that radiation breakdown is at a minimum is attributed in part to the aromatic nature of the enclosing molecules.

Safety Considerations

The quinol-Kr^{85} clathrate is among the safest forms of radioactivity. Kr^{85} is virtually a pure beta emitter (10.3-yr, 0.67-Mev beta) and does not require heavy shielding for safe handling. When released from the clathrate cage, it is rapidly diluted and carried away by the surrounding atmosphere. Even if accidentally inhaled, it is incapable of being metabolized or absorbed by the body. In addition, its decay product is a stable nuclide; so the radiation is only that originating from krypton.

Usefulness

We have begun work on many applications. Among the most interesting are:

Detection and measurement of nonradioactive compounds. Certain materials can be measured in a special sensing cell. The material oxidizes the clathrate and releases an amount of

radioactive krypton proportional to the amount of material under analysis. Released krypton is then measured by conventional radiation detectors.

An experimental air-pollution monitor operating on this principle has recently been demonstrated by Tracerlab. It is sensitive to SO_2, O_3, ClO_2 and other contaminants in the parts-per-billion range.

These radioactivity determinations are far more sensitive and easier to make than similar low-level determinations dependent on chemical and physical changes. Other advantages are the speed and ease of reading, low cost and portability of the simple and rugged instrumentation based on this principle.

Thickness gaging. Present backscatter gages use a Sr^{90} source, which emits 2.2-Mev betas. Many of these high-energy beta particles completely penetrate the product and are deflected by the internal magnetic structure of the roll. In light materials, this effect predominates, and so backscatter techniques can be used only with heavy materials. Gaseous Kr^{85} has been used for this application, but the amount of activity required makes the source excessively large. It is not possible to reduce the size by compression; this would require the use of a heavy-walled material which would absorb too many of the relatively soft betas.

X-ray sources. X-rays and bremsstrahlung are useful for heavy-materials gaging, radiography, X-ray diffraction and fluorescent analysis. An X-ray source can be produced by mixing with the clathrate crystal one or more elements that emit the desired energy.

Static elimination. In this application there are advantages from the safety standpoint. In case of accidents or damage, Kr^{85} will disperse as a gas.

Light sources. Clathrate compounds can be made with a scintillator such as zinc sulfide to provide high-intensity light sources. In addition, much larger amounts of activity can be incorporated to provide lamps of greater brightness with low inherent biological hazard.

* * *

The work described here has been done under the auspices of the Office of Isotopes Development, U. S. Atomic Energy Commission.

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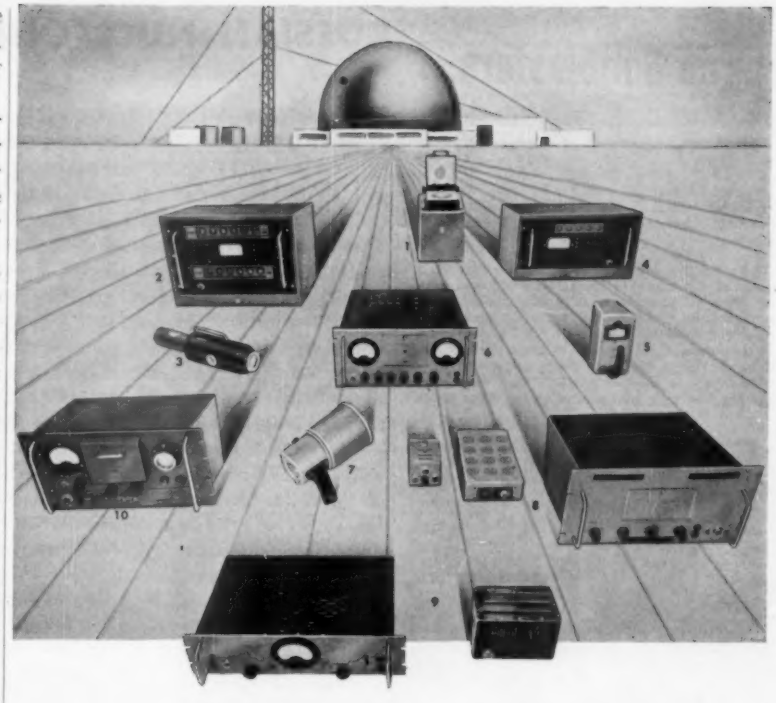

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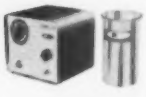

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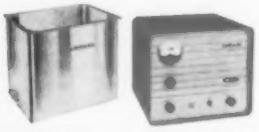
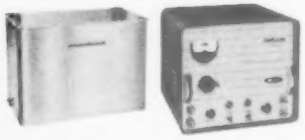
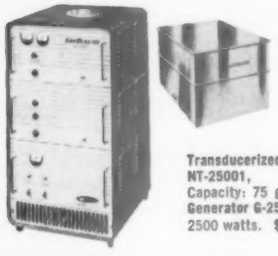


Transducerized Tank NT-1505, Capacity: 5 gallons; **Generator G-1501,** 300 watts. **$695.**



Transducerized Tank NT-5001, Capacity: 10 gallons; **Generator G-5001,** 500 watts. **$1325.**



Transducerized Tank NT-25001, Capacity: 75 gallons; **Generator G-25001,** 2500 watts. **$4360.**

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RUSSIAN NUCLEONICS

Beta-Active Paint Scuttles Barnacles

Russian workers are exploring the use of beta-active paints to frustrate the marine organisms that usually foul boat bottoms; glass test plates have been painted with Y^{91} and suspended 1 meter below the surface of 3-meter-deep water. [M. A. Dolgopolskaya, L. A. Il'in, I. A. Puzanov, V. A. Tsenev, *Atomnaya Energiya* **6,** 674 (1959)]. It appears that surface concentrations of 0.05 mc/cm² or more guarantee freedom from barnacles, whereas smaller concentrations (3 μc/cm²) stimulate rather than inhibit growth of the fouling organisms.

The yttrium was dissolved in 3 *N* hydrochloric acid, mixed with a water emulsion of polyvinylacetate and painted on the plates. After a heat treatment, the plates were lacquered and immersed in water. Repeated tests of the plates showed a decay of activity with the half-life of Y^{91} (58 days; 1.54-Mev betas); thus the radioactivity was not escaping by diffusion or abrasion.

Controls had the same polyvinylacetate and lacquer coating but no radioactivity. The first observation after 10 days' immersion showed some barnacle growth on the radioactive plates but not as much as on the controls. Subsequent inspections at 61 and 102 days showed that the barnacles on the radioactive plates had dropped off while three layers had grown on the controls. The tests were made at the period of greatest larva activity—August 6 to November 16, 1957.

Further work is searching for solutions to practical problems in applying the method and looking for a longer-life beta emitter to replace the Y^{91}.

Gel Counting for Accurate Bioassay

Scintillation gel counting can provide almost 100% counting efficiency with small concentrations of beta emitters in biological samples including small ones from the human body. Soviet researchers grind the specimen tissue or its ash, wet with liquid scintillator and then mix with scintillating gel. [D. G. Fleishman, L. G. Shahidzhanian, *Atomnaya Energiya* **6,** 669 (1959); L. G. Shahidzhanian et al., *Doklady Akad. Nauk SSSR* **125,** No. 1 (1959).]

The gelling agent is methyl methacrylate (American Lucite or Plexiglas; Russian "pleksiyglasa"). It is first partially dissolved in toluene, then added to a liquid scintillator (4 gm/liter *p*-terphenyl and 0.1 gm/liter POPOP in toluene) The solution is heated to 100° C and held at that temperature for a few minutes to form the gel. The method is similar to a method of Hayes' that uses polystyrene [*IRE Trans. on Nuclear Science* **5,** No. 3, (1958)] and not unrelated to one, previously reported in NUCLEONICS, that uses unheated Thixcin as a gelling agent [C. G. White, S. Helf, NUCLEONICS **14,** No. 10, 46 (1956)]; see also p. 160 this issue.

The quantity of methyl methacrylate can be varied widely, but 5–8% by weight appears to be best. A Co^{60} source produces pulses of the same height that it does in the liquid scintillator without gelling agent. For a 100–300-mg sample, 0.5 ml of liquid scintillator and 20 ml of the scintillating gel are used. With photomultipliers FEU-S and FEU-1BS, one has a background of ~30 cpm and practically 100% counting efficiency with K^{40}, Sr^{90} and Cs^{137}.

Pulsed Reactor for Irradiation Tests

An article last year by T. N. Zubarev [*Atomnaya Energiya* **5,** No. 12, 605 (1958)], discusses a homogeneous pulsed-reactor design which achieves peak fluxes in the core of 10^{17} n/cm² sec. The reactor is similar in idea to General Atomic's FLASH reactor (NU, Sept. '58, p. 81); the GA version would pulse at 6×10^{17} n/cm² sec with a pulse length of a few milli-seconds. In the U. S. design the pulses are controlled by the heating of the solid moderator while in the USSR reactor changes in reflection provide control.

The Soviet author speculates on the possibility of combining several of the homogeneous fuel units into an irradiation facility in which an average thermal flux of 10^{17} n/cm² sec would be available.

Although Russian scientists at the Soviet Exhibition in New York revealed that two pulsed reactors are now being built at Dubna (one a TREAT-type thermal reactor and the other a fast reactor with a rotating specimen platform), no plans have been mentioned yet to build the homogeneous pulsed reactor.

* * *

The above accounts are based on material translated from the Russian by F. Kertesz and J. S. Lewin, ORNL, Oak Ridge, Tenn.

BOOKS

Radioisotopes in Scientific Research

Vol. 1: Research with Radioisotopes in Physics and Industry

Edited by R. C. EXTERMANN (Pergamon Press, London, 1958, 761 pages, $22.50)

Reviewed by D. E. HULL, California Research Corp., Richmond, Calif.

Here in four volumes is preserved an invaluable record of a historic conference, in which scientists from 61 countries met to discuss their experiences in applying radioisotopes to all kinds of scientific research.

Altogether, 229 papers were given, and the first volume includes 55 classified as being in physics or industry. The text of eight of these is in French, the rest in English; abstracts of all papers are provided in English, French, Russian and Spanish. The contents of so rich a compendium of many diverse papers can only be skimmed in this brief review.

Methods for producing radioisotopes are first described. The bizarre effects created by the modern alchemist with his prolific supply of neutrons continues to amaze the chemist of an earlier generation.

Papers on tracer studies of alloys and metallurgical processes are the strongest part of the book. Tracer atoms in an alloy transported by an electric current showed surprisingly that the carbon in austenite moves toward the cathode, while the iron moves toward the anode at 900° and is immobilized at higher temperatures. Grain-boundary diffusion predominates at lower temperatures but is equaled by volume diffusion at higher temperatures, as seen both in radioautographs and in analysis of surface activity vs. time curves. In industrial applications, the physical movement and chemical reactions of both ore and coke in blast furnaces are followed with tracers. Inclusions of slag or of refractory furnace linings in steel ingots are readily spotted with radioisotopes. The wear of a hard metal rubbing against a soft one is influenced by its surface treatment.

Listed among industrial applications, but actually opening the gate wide to a new field in physical chemistry, is a paper on the solubility of solids in high-pressure steam. The key that opens the gate is the extreme sensitivity of radioisotope techniques, making it possible to measure concentrations as low as 10^{-5} ppm. Applications of these results in steam-turbine technology, as well as in geochemistry, are of great importance. Fluid density, porosity of coatings, clearance of turbine blades, and mechanism of ore flotation are subjects of other papers in this session.

Diffusion of tracer ions in alloys, salts, oxides and oxide or sulfide films on metals are described in a variety of papers. Thermal reactions in solid oxides are followed by changes in emanation of thoron, and thermodynamic properties of metals and nonmetals are measured in ideally dilute solutions in ore-smelting chemistry.

Numerous techniques, old and new, are described in absolute counting, liquid-scintillation counting, and neutrino detection. Fine-grained emulsions give closer resolution of nuclear tracks of fission fragments as well as of relativistic electrons. An array of tiny G-M tubes for scanning a surface is delightful for its simplicity and efficiency.

Russian contributions to this volume are noteworthy for quantity and their generally good quality, particularly in solid-state research and metallurgy. Their 19 papers exceeded the total from England, U. S. A., and Canada. Clarity of the Russian papers varies greatly; some are very well organized and clear at first reading; others leave even a careful reader confused as to how the results were obtained by the means described.

The high price of this volume will discourage many from owning a personal copy. But it ought to be in the library of every institution where radioisotopes are used in industry or the physical sciences.

Nucleonics Fundamentals

By DAVID B. HOISINGTON (McGraw-Hill, New York, 1959, xii + 410 pages, $9.50)

If there is intellectual progress in the world, a measure of it is the way that knowledge is reorganized. Newton's Laws, which were the discovery of one man, are now the property and tool of every thinking person over the age of 12—and probably many others.

This book recognizes that while senior physicists made and operated the first piles, the reactors of the future and the nuclides they produce will be in the hands of younger people. Training for the nuclear field must start earlier and extend more broadly than in the past.

The coverage of this volume is broad, extending to atomic structure, radiation protection, accelerators, fission, fusion and neighboring topics. The treatment is authoritative. Professor Hoisington is at the U. S. Naval Postgraduate School, and his book grows from his course there. It is plain that he reads widely and quotes both figures and thoughts with wisdom and discrimination.

No book is without errors, and the well informed reader will find some minor ones here. How material is best organized is a matter of opinion, and the reader may disagree with Professor Hoisington in some respects. For example, this reviewer questions the necessity of including the elements of vector analysis in the early pages. Some of the material seems more appropriate to a physics course even at this stage of our nuclear advancement. But the book is a large step forward toward organizing the atom for its great potential in peaceful applications.

—R. H. E.

Organic Syntheses with Isotopes: Part I, Compounds of Carbon; Part II, Organic Compounds Labeled with Isotopes of the Halogens, Hydrogen, Nitrogen, Oxygen, Phosphorus and Sulphur

By ARTHUR MURRAY III AND D. LLOYD WILLIAMS (Interscience Publishers, New York, 1958, Part I—1,146 pages, Part II—950 pages, $25 for each part).

Reviewed by BERT M. TOLBERT, Chemistry Dept., University of Colorado, Boulder, Colo.

The end of World War II marked the beginning of a period during which the use of isotopes was intensively developed. Thousands of labeled compounds were synthesized, mostly by standard procedures of organic chemistry scaled down to a few millimoles reaction. In spite of the ordinary chemistry, these new preparations usually required considerable development work as the limiting or expensive reagent was often different from that described in the published preparations, and the cost of the isotopic material usually dictated very high yield requirements.

This pair of books by Murray and Williams now brings together all of this material dealing with the synthesis of labeled compounds. In many cases the references for these preparations have been derived from obscure AEC reports that are no longer available. In other cases the preparations can be

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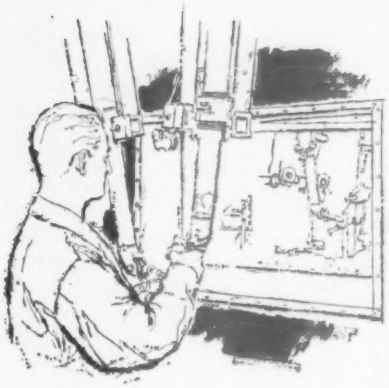

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BOOKS

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found in books or papers equally difficult to examine. It is therefore a unique book in that there is no equivalent collection of isotopic synthesis material available.

This is a very appropriate time to write such a book. The period of intensive development of synthetic procedures for the preparation of labeled compounds was coming to a close in 1955 when Murray and Williams ended their attempts to systematically cover the literature. Furthermore, the demand for labeled compounds had developed to such a degree that a number of private companies had undertaken commercial production of the more important chemical and biological intermediates. As a result, only work of a special nature, such as syntheses involving short-lived isotopes or difficult and special compounds, was being continued to any great extent in the research laboratories. Today there are fifty-six commercial isotope suppliers listed in the "Isotopes Index" published by the Scientific Equipment Co., Indianapolis, Ind.

Except for a short introduction of 24 pages, "Organic Syntheses with Isotopes, Part I and Part II," is devoted exclusively to synthetic procedures. Biological preparations are not included, although in a number of cases this is unfortunate because for many compounds this is the preferred synthetic procedure.

In the book, each preparation follows a standard format: the labeled-compound name, the equation for the best preparation and the synthetic procedure. Additional methods are given, then notes on the several methods and finally a discussion of other preparations together with references. For a reasonably good organic chemist, sufficient experimental detail is given to carry out syntheses without consulting the original literature. This detail is very helpful in the case of obscure journals or reports. The extensive background of Murray and Williams has enabled them to do a very good job of evaluating the several procedures available for the synthesis of a given compound.

Isotopic nomenclature is a problem; no definite rules have been produced by the ACS for the naming of such compounds because of discrepancies between the nomenclature rules of the International Union of Pure and Applied Chemistry and nomenclature cus-

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toms in this country. Therefore Murray and Williams have adopted a nomenclature system based upon their own experience as well as on the several published reports in this area. By and large I think that their nomenclature system is very satisfactory and might well be adopted in our chemical literature. The label in the compound is defined by adding a locant and an isotope designation to the end of the name or the end of the particular part of the name for which the label is applicable. The only feature of their nomenclature procedure that I do not care for is that indefinite or generally labeled compounds are described by placing the isotope designation before the name. This results in a confused index system and places too much importance on an arbitrary nomenclature rule.

There is no separate index for Part I of this pair of volumes. I feel sure that many people would like to buy Part I only since this section of the material is much more commonly used than that in Part II. However, because of the rather complex system of arranging the compounds, Part I is of limited value without an index. I think that the publishers would get more extra sales by the individual buyers who want only Part I than they would lose in sales of Part II.

In conclusion, this is an outstanding reference work and an essential part of every chemical reference library. The authors, the Atomic Energy Commission and the Los Alamos Scientific Laboratory are all to be congratulated for a real contribution to tracer technology.

Geneva '58 Proceedings*

Vol. 19, The Use of Isotopes: Industrial Use (366 pages, $12.50) has the 53 papers presented at Sessions 5b (Progress in the Use of Isotopes) and D-7 (Use of Isotopes in Industry). The subjects vary from steel to medicine; countries represented include Czechoslovakia, Japan, Canada, Hungary, Rumania, U. S. and U. S. S. R.; representative authors are Erwall, Spinks, Putman, Aebersold, Topchiev. As in most Geneva volumes, the reader will be annoyed at the overlap in papers entitled "Applications of Isotopes in Research and Control," "Measurement and Control Methods Using Radiation," "Industrial Applications of Radioisotopes," "Applications of

* Other Geneva Volumes were reviewed in the July '59 NUCLEONICS, p. 105.

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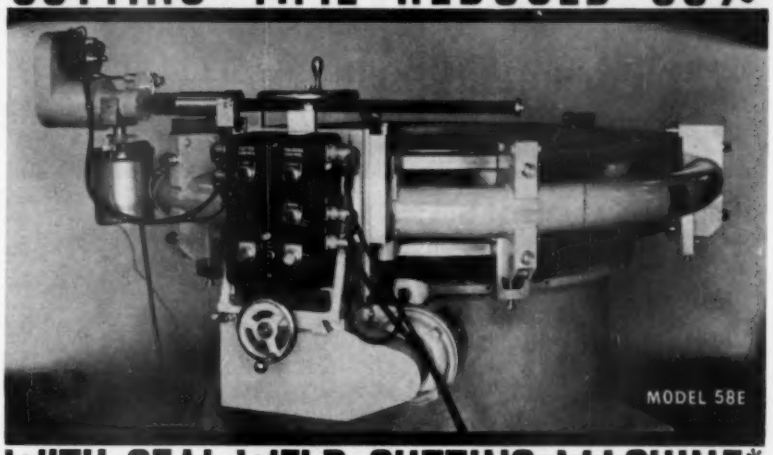

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Radioisotopes," "Developments in Industrial Applications of Isotopes." However, there are some kernels for the gleaning, and the patient reader can learn much of the partnership between industry and radiation.

Vol. 21, Health and Safety: Dosimetry and Standards (249 pages, $10.50) contains the material from Sessions 5a (Operational Experience in Health and Safety) and D-15 (Dosimetry and Standards). The 11 papers of the first of these sessions are full of the statistics that lead to mpc's and reactor safety systems. The remaining 37 papers cover such active areas as low-level counting, modern dosimetry, units and calibrations. Westerners will probably find the greatest novelty in a 10-page paper on safety in Russia's nuclear-powered ice breaker.

Vols. 24 and 25, Isotopes in Biochemistry and Physiology, Part 1 (297 pages, $11.00) and **Part 2** (301 pages, $11.00), respectively, include the papers of sessions D-13 and D-14, respectively. The first volume of 59 papers is devoted to organic metabolism, protein synthesis, studies using deuterium and tritium, and endocrinology. The second includes 59 papers on a UN survey, photosynthesis, cellular metabolism, hematology, ion transport, mineral metabolism, therapeutic compounds and "new techniques." The reader will find much productive research in the fields of biology and medicine, much less that is new in nuclear technology.

BOOKS RECEIVED

Dictionary of Nuclear Physics, edited by Hans Rau (Brandstetter Verlag, Wiesbaden, Germany, 1958, $3.50, 247 pages). This German-English, English-German dictionary includes 5,000 terms and 600 symbols and abbreviations.

Radiation Hazards and Protection, by D. E. Barnes and Denis Taylor (Pitman Publishing Corp., New York, $6.75, 178 pages). This introductory book describes the problems and necessary steps for personnel protection through shielding and instrumentation.

Successful Technical Writing, by Tyler G. Hicks (McGraw-Hill Book Co., New York, 1959, $5.50, 294 pages). The

author provides the technical writer with the basic skills of writing and then describes the refinements of writing business-paper articles, reports and books.

Astronomy, by Theodore G. Mehlin (John Wiley & Sons, New York, 1959, 392 pages, $7.95).

Magnetic Amplifier Engineering, by George M. Attura (McGraw-Hill Book Co., New York, 304 pages, $7.50).

Heat Transfer Engineering, by Hilbert Schenck, Jr. (Prentice-Hall, New York, 310 pages, $9.25).

Nuclear Scattering, by K. B. Mather and P. Swan (Cambridge University Press, New York, 1958, 469 pages, $14.50).

Radiation Biology and Cancer (The University of Texas Press, Austin, 1959, 493 pages, $8.50). A collection of papers presented at the 12th annual Symposium on Fundamental Cancer Research at The University of Texas, 1958. Included are fundamentals, techniques, research with mice and men, and case studies.

Cerenkov Radiation and Its Applications, by J. V. Jelley (Pergamon Press, New York, 1959, 304 pages, $10).

Protection in Diagnostic Radiology, edited by B. P. Sonnenblick (Rutgers University Press, New Brunswick, N. J., 1959, 346 pages, $7.50).

Lectures on Nuclear Theory, by L. Landau and Ya. Smorodinsky (Plenum Press, New York, 1959, 108 pages, $5.25). Translated from the Russian; these lectures were originally presented to experimental physicists.

Proceedings of the Rehovoth Conference on Nuclear Structure, edited by H. J. Lipkin (Interscience Publishers, New York, 1958, 614 pages, $12.50).

Feedback Control Systems—Analysis, Synthesis, and Design, by J-C Gille, M. J. Pelegrin and P. Decaulne (McGraw-Hill Book Co., New York, 793 pages, $16.50).

Atomic Medicine, 3rd ed., edited by Charles F. Behrens (The Williams & Wilkins Co., Baltimore, 1959, 705 pages, $15). Reflecting current problems, new material has been added on

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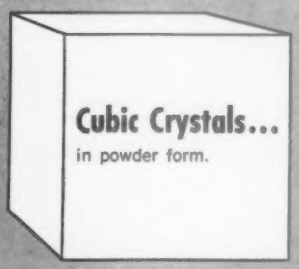

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BOOKS

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whole-body irradiation, fallout and radioisotope ingestion.

Circuit Theory of Linear Noisy Networks, by H. A. Haus and R. B. Adler (The Technology Press of M. I. T. and John Wiley & Sons, New York, 1959, 79 pages, $4.50).

ALSO OF NOTE

A Survey of Atomic Energy Development in 14 Countries. Republication, partially translated, of a book published in 1958 in Sweden. 123 pages. *Studieförbundet Näringsliv och Samhälle, Direktör Torsten Carlsson, Sköldungagatan 2, Stockholm, Sweden.*

Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure. National Bureau of Standards Handbook 69 (supercedes Handbook 52). 95 p., 35¢. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

Source Material for Radiochemistry. National Academy of Sciences—National Research Council Publication 654. Bibliography emphasizing documents and reports of a review nature. Free. *Div. of Physical Sciences, NAS-NRC, 2101 Constitution Ave., Washington 25, D. C.*

Vanderbilt Law Review—A Symposium on Nuclear Energy and the Law, Vol. 12, No. 1, Dec. '58. Articles cover various aspects: lawyer's duties, international cooperation, world trade, radiation injuries, reactor safety, workmen's compensation, labor relations, antitrust provisions, Federal support and legal aspects in the U. K. $2.00. *Vanderbilt University Press, Nashville 5, Tenn.*

Détecteurs de Particules—Compteurs et Scintillateurs, by Daniel Blanc (Masson et Cie., Paris, 1959, 323 pages, 3.900 fr).

Rapport Annuel—1958. L'Institut Interuniversitaire des Sciences Nucléaires, 11, Rue d'Egmont, Bruxelles 5, Belgium.

Proceedings of the 1957 Fast Reactor Information Meeting. Meeting held at Chicago, Nov. '57, sponsored by the

AEC Civilian Power Reactor Branch of the Reactor Development Div. 282 pages, $2. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

Information Meeting on Gas-Cooled Power Reactors (TID-7564). Meeting held at Oak Ridge National Laboratory, Oct. '58. 372 pages, $3.50. *Office of Technical Services, Department of Commerce, Washington 25, D. C.*

Papers Presented at the Controlled Thermonuclear Conference (TID-7558). Meeting held at Washington D. C., Feb. '58, sponsored by AEC Controlled Thermonuclear Branch, Div. of Research. 528 pages, $4.75. *Office of Technical Services, Department of Commerce, Washington 25, D. C.*

First All-Union Conference on the Synthesis and Investigation of Scintillators for the Detection of Nuclear Radiation. English translation of the Bulletin of the Academy of Sciences of the U. S. S. R., Physical Series, Vol. 22, No. 1, 1958. 93 pages, $20. *Columbia Technical Translations, 5 Vermont Ave., White Plains, N. Y.*

Energy Spectrum Resulting from Electron Slowing Down (NBS Circular 597). 16 pages, 20¢. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

Safe Handling of Radioisotopes. This is the first publication of the International Atomic Energy Agency in Vienna. The recommendations are the work of an international panel. 99 pages, $1. *The UNESCO Publications Center, 801 Third Ave., New York 22, N. Y.*

Semi-Empirical Neutron Cross Sections, Part II, Vol. I, 0.5–15.0 Mev. (UCRL-5351). This report, by R. J. Howerton, presents curves based on the raw data of UCRL-5226 (Tabulated Neutron Cross Sections, Part 1) by the same author. 274 pages, $4. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.*

Report of the Joint Program of Studies on the Decontamination of Radioactive Waters (ORNL-2557). Studies jointly made by the ORNL Health Physics Div. and the Robert A. Taft Sanitary Engineering Center of the U. S. Public Health Service. 62 pages, $1. *Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.*

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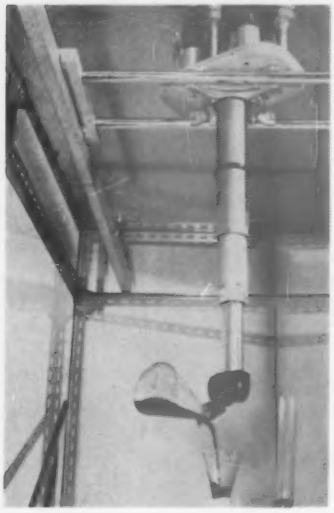


←Magnetic Manipulator

Magnetic fields comprise the basic linkage between the in-cell and out-of-cell members of a new-type master-slave manipulator and hot cell designed in France. The top of the cell is nonmagnetic steel ⅛ in. thick to permit penetration by the magnetic fields. The in-cell portion of the manipulator consists of four magnets, a telescoping tube and tongs. Horizontal movement of the slave arm results from the magnets following the four corresponding out-of-cell magnets. Rotational movement by the magnets about their axes is similarly duplicated. Rotation of two of the magnets displaces racks and pinions that control the grip of the tongs and the rotation of the arm. A third magnet controls vertical movement by means of tapes and pulleys; the fourth controls the rotation of the tongs. The out-of-cell housing is attached to a set of rails that allows it unlimited horizontal movement. All master movements are provided by electric motors actuated from a control "arm." American Lip Corp., 610 5th Ave., New York 20, N. Y.; Lip S.A., 25 Boulevard Malesherbes, Paris 8, France.

Sump Filter Pump

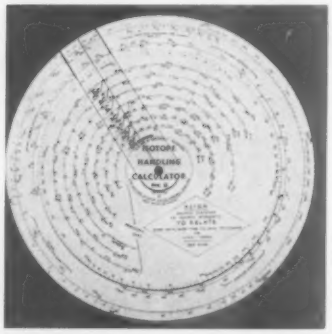
A detachable filter chamber providing flexible filtration and agitation for solutions as hot as 250° F is featured on Model UAL-20 sump filter pump. The sump pump is fabricated from high-temperature epoxy resins; its shaft can be 316 stainless, Hastelloy C or titanium. Filter chambers are available in high-temperature Lucite or epoxy, pvc or Teflon. Thorough depth filtration down to 1 micron is provided by filter tubes of cotton or Dynel, and porous stone or porous carbon filter tubes are also available. Both ⅜- and ½-in. pumps can deliver 900 and 1,500 gal/hr respectively, are available.—Sethco Manufacturing Corp., 2284 Babylon Turnpike, Merrick, N. Y.

Gamma Alarm

Model GA-2 detection and gamma alarm system is a single unit that operates on 110 volts. The wall-mounted unit can be used with remote recording and auxiliary control devices.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Planchets

Raised concentric rings are now stamped in the bottom of stainless steel planchets. The raised rings restrain liquid samples from running toward the wall of the planchet, resulting in more uniform drying and greater counting accuracy.—Atomic Accessories, Inc., 244-02 Jamaica Ave., Bellerose 26, N. Y.



Isotope-Handling Calculator

A single setting of the isotope-handling calculator (above) interrelates the values for source strength, gamma-dose rate, distance from source and shielding by lead. Direct-reading values are given for Na^{24}, Co^{60}, Ra, Ta^{182}, Au^{198}, Ir^{192} and I^{131}.—Isotope Information Office, Harwell, England.

Ultrasonic Cleaning System

Sonogen Model H-100 ultrasonic cleaning system has been integrated into a single, compact cabinet. The rinse tank, cabinet and transducerized cleaning tank are stainless steel. Transducerized rinse tank, heaters and recirculating filter can be added.—Branson Ultrasonic Corp., 40 Brown House Rd., Stamford, Conn.

Proportional Counter

Type PX 115 high-resolution proportional counter has energy resolution below 100 kev thereby extending the range of γ-ray spectrometers to 20 kev. The operating-voltage range of the 2½-in.-dia × 16-in. counter is 3,500–4,200 volts. Xenon-methane gas is utilized at 2 atm absolute; multiplication factor is 60 volts/db.—20th Century Electronics Ltd., New Addington, Croydon, Surrey, England.

Special Stainless Steel

A low-carbon, low-cobalt, low-boron 18-8-type stainless steel is produced on special order. The alloy is available in annealed and pickled, welded and drawn grades. Typical analysis of the alloy is:

C	*Mn*	*Si*	*S*	*P*	*Cr*
0.024	1.68	0.45	0.010	0.018	18.64

Mo	*Co*	*Cu*	*B*	*N*
<0.08	~0.0016	<0.06	<0.0005	12.54

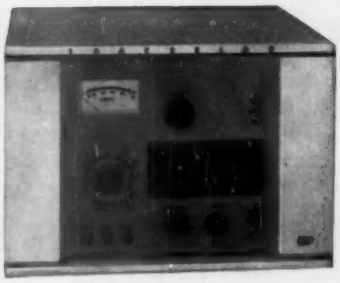
Union Steel Corp., Union, N. J.

Sprayed Asbestos

Thermal and acoustical insulation were provided at the MIT reactor by spraying the interior of the steel dome with a 2-in. blanket of asbestos (above). High

SC-71 Compu/Matic II Scaler

SC-73 Versa/Matic II Scaler



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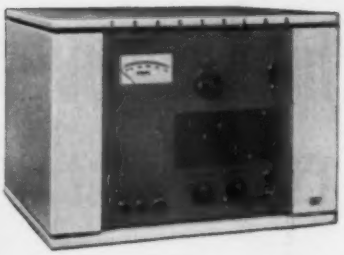

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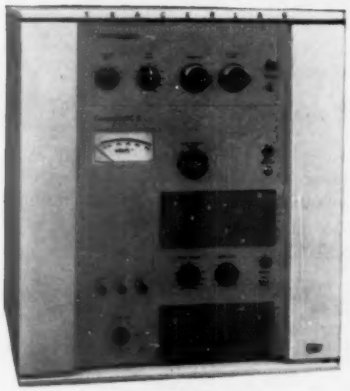

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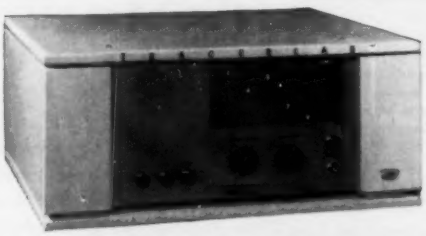

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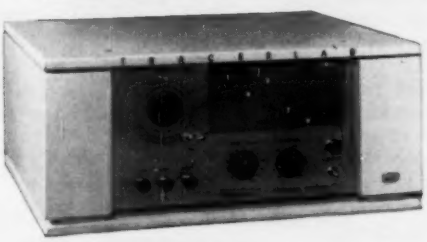

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High-temperature, vacuum-tight electrical connectors feature ceramic insulation formulated to avoid neutron-absorbing materials. Prestressed ceramic inserts are fired into 300-series stainless-steel shells. The connector, which maintains high electrical resistance up to 1,200° F, is available in most configurations including subminiature sizes.—Technical Industries Corp., 389 N. Fair Oaks Ave., Pasadena, Cal.

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A fire-resistant space filter is at least 99.97% efficient in removing particles of 0.3-μ diameter. The filter can operate in air streams with up to 100% relative humidity. Mean pressure drop at rated capacity is 0.85 in. of water.—Mine Safety Appliances Co., Pittsburgh, Pa.

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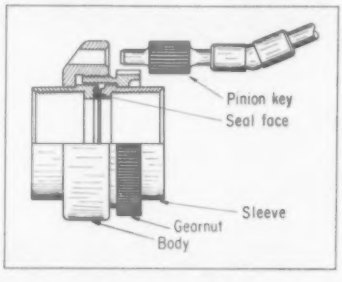

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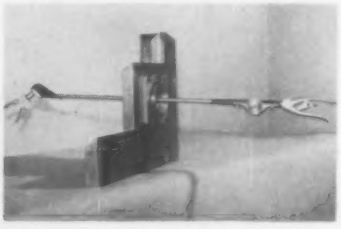

Laboratory Manipulator

Model T5 manipulator (above) incorporated a universal ball-joint to permit its operation through lead-brick walls. The specially designed joint, which is an effective shield, is fitted in a 2-in. thick lead brick. Both the joint and the shaft of the manipulator can be either freely rotated or locked at a specific angle. The head of the tool is offset at a 45° angle and rotates 370°. The pressure exerted at the claws can be set at a predetermined amount that will not be exceeded regardless of the pressure applied at the handgrip. Stock lengths of the manipulator are 3½, 5, 6 and 8 ft.—Nuclear Research Applications, Ltd., Bell St., Reigate, Surrey, England.

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Type 656 Gamma detector can be used alone as an inexpensive fail-safe radiation alarm. The detector element is a metal Mullard halogen-quenched G-M tube which operates at 110 and 220–250 volts. The detector gives 100 cps for 1 mr/hr for γ-rays from Co^{60}. Standard response time is 8 sec, although the response-time constant can vary from 0.5 to 16 sec. The instrument may be used with γ sources as a gamma gage.—Isotope Developments Ltd., Beenham Grange, Aldermaston Wharf, Berks, England.

Decade Scaler

Model DS-1H is a utility counting and registering instrument with input systems for scintillation, proportional, G-M and neutron detectors. Counting errors resulting from tube or component failure in the scaling circuit are automatically signaled by an ambiguous indication in the strip. The instrument can register 10^6 cpm.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

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Model AM-3A air monitor (above) features four interchangable detectors sensing α, β, β and γ or α, β and γ radiation. The last named is most sensitive and consists of a Mylar-window flow G-M tube. The moving filter permits immediate detection of first surface deposits as collection occurs or delayed detection with a fixed step-wise moving or continuously moving filter. Model AM-2A has only the α, β and γ detector.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

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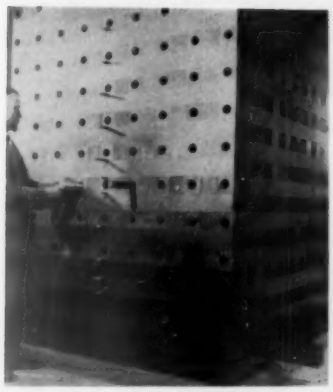

Graphite for Subcriticals

The Kansas State College reactor (above) is composed mainly of bars of R-1HLM nuclear-grade graphite. The 4-in.^{2} bars were precision-machined to tolerances of $\pm$0.010-in.—Great Lakes Carbon Co., Electrode Div., Niagara Falls, N. Y.

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A sharply-focused beam of electrons in a high-vacuum chamber is used to fusion-weld a wide variety of mater als. Model B-1520 welding machine can accommodate tubing or parts up to 3⅛-in. dia and 10 ft long. Turntable can be installed for spot-welding quantities of small parts.—High Vacuum Equipment Corp., 2 Churchill Rd., Hingham, Mass.

Survey Meter

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- **Consultation** on the A1W—basis for the nuclear aircraft carrier *Enterprise*
- **Engineering** the new high level examination laboratory for NRL, Washington, D. C.
- **Turn-key responsibility** for the CAMEN (Italian Navy) research reactor to be built in Livorno.

Here too, Vitro is making vital contributions as it has on land and in the air. Typical of these achievements are the Lockheed center at Marietta, Ga., where the first atom-powered plane is now being developed, and Con Edison's Indian Point, N.Y., nuclear station.

In today's modern technological areas, diverse nuclear and engineering skills are a necessity, not a luxury. Vitro couples these skills with *experience in depth.* Finding an answer to your needs can start right now.

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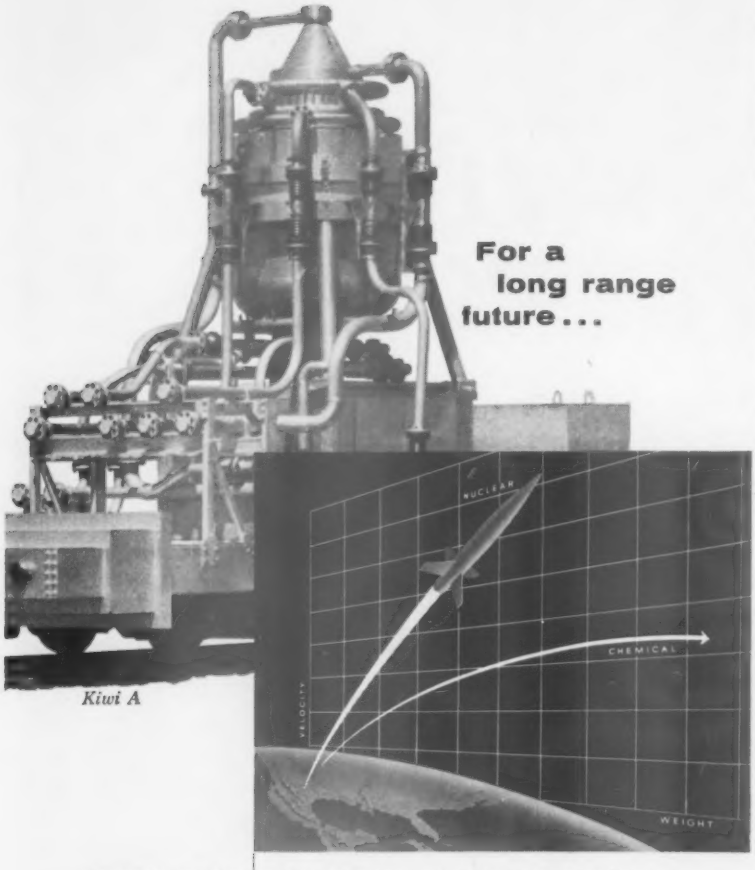

Kiwi A

NUCLEAR ROCKET PROPULSION

One of the most important programs at Los Alamos is Project Rover—research and development work aimed at utilizing nuclear energy for rocket propulsion. Investigations are being made in the fields of heat transfer, neutronics, fluid dynamics and rocket engine controls. Of special interest is the field testing of reactor concepts.

The Laboratory is interested in inquiries from physicists, physical chemists, metallurgists and engineers who wish to engage in any phase of this well-rounded research program.

Write to:

Director of
Personnel
Division 59-87

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scientific laboratory
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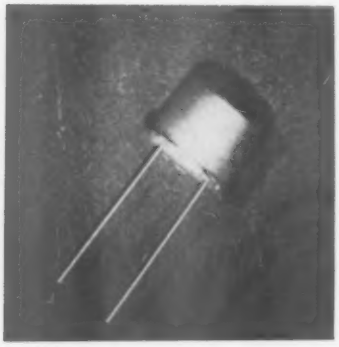
LOS ALAMOS, NEW MEXICO

nated wipers are collected and burned daily in a specially-designed incinerator. Gases from combustion are scrubbed by a water-spray to remove impurities, and the ashes disposed of in resin storage tanks.—Industrial Packaged Products Div., Scott Paper Co., Chester, Pa.

Poppet Check Valve

A special spring assembly eliminates chatter in a poppet-type check valve. The unit is furnished in brass, stainless steel, Monel, aluminum and other machineable materials. Only 2⅛-in. long, the valve is available with Swagelock ends.—Nuclear Products Co., Cleveland 10, Ohio.



Tunnel Diode

The tunnel diode (above), which is smaller, faster and more rugged than a transistor, utilizes the physical phenomenon of quantum-mechanical tunneling. Oscillation frequencies above 2,000 Mc have been obtained, and 10,000 Mc are anticipated. Minimum power requirement is 10^{-6} watts. Switching-type diodes have functioned in 0.1 mμsec. Since structural perfection of the crystal is less important than in transistors, the device is resistant to radiation damage; exposure to 10^{14} nvt has revealed no damage. Silicon, germanium, gallium arsenide, gallium antimonide and indium antimonide have been used for tunnel diodes. Limited quantities of experimental diodes are available.—General Electric Co., Semiconductor Products Dept., Syracuse, N. Y.

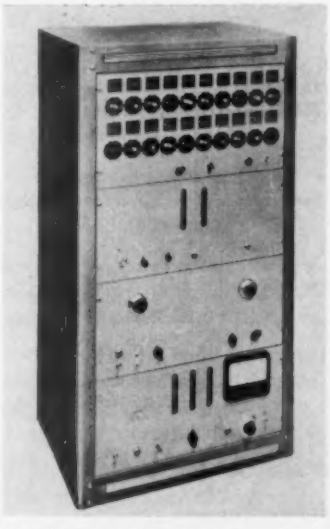
Vacuum-Tube Electrometers

Models VTE-0 and VTE-1 measure the current range 10^{-3} to 10^{-11} and VTE-2 from 10^{-3} to 2×10^{-13} amperes. The latter two instruments feature a

built-in bucking current supply for observing extremely small fluctuations in a current source.—The Victoreen Instrument Co., 5806 Hough Ave., Cleveland, Ohio.

Neutron Survey Meter

A high-sensitivity fast-neutron survey meter (above) is not sensitive to slow neutrons and is not affected by γ-rays from Co^{60} up to 4 r/hr. The detector has ZnS grains dispersed and molded in Lucite which supplies the photon recoils. Three linear ranges of sensitivity are calibrated for 0–5, 0–50, and 0–500 neutrons/cm²/sec.—Nucleonic Corp. of America, 196 Degraw St., Brooklyn 31, N. Y.



100-Channel Analyzer

Model PHA-120 pulse-height analyzer (above) makes and reads 100-channel analyses in 5 steps of 20 channels. The instrument permits exact alignment of end channels of 20-channel groups and "zero level" adjustment,

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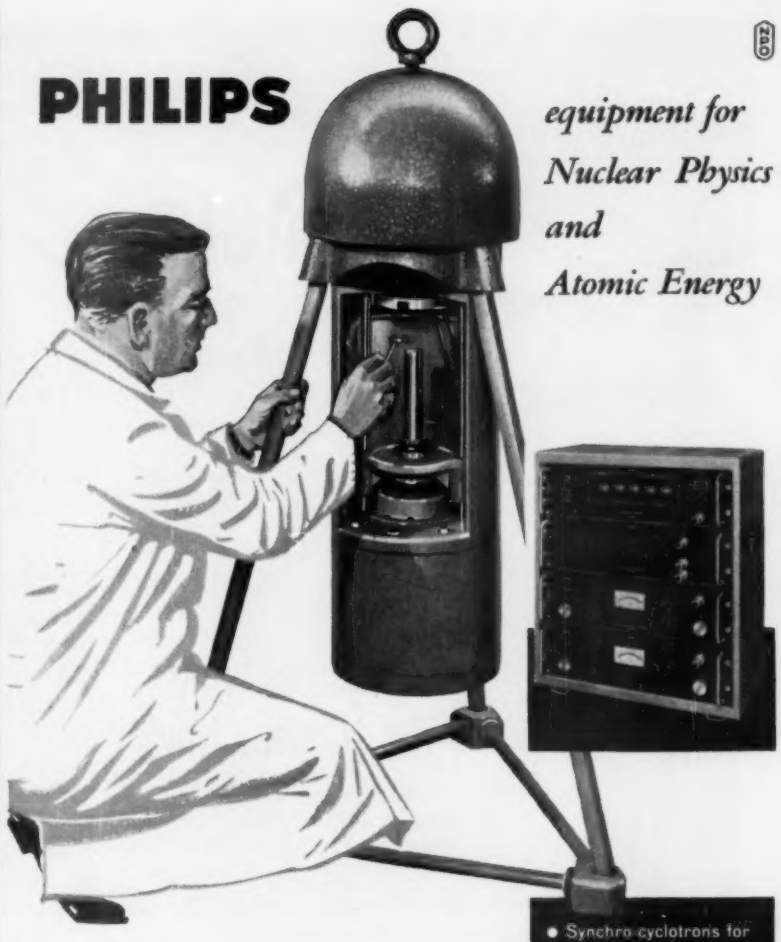
equipment for Nuclear Physics and Atomic Energy



Generally low-level beta-counting involves the use of relatively cumbersome and heavy equipment, which occupies quite a lot of laboratory space. Thanks to the introduction of a new type of guard counter, an invention of the Philips Research Laboratories, it was found possible to solve space and weight problems in a neat way. Shown here is the Low-Level Beta-Counting Arrangement, type PW 4127, and its corresponding measuring equipment. Background-reduction to less than 1.3 c.p.m. is obtained with a thin end-window counter used for measuring low-energy betas, and to less than 1.5 c.p.m. with an end-window counter for general low-intensity work.

The shielding comprises 30 mm of special lead, some 250 years old, with an extremely low specific activity, and 100 mm of iron.

- Synchro-cyclotrons for various final energies.
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- Linear electron accelerators.
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- Radio-active isotopes.
- Air & gas liquefiers.
- Vacuum measuring equipment.

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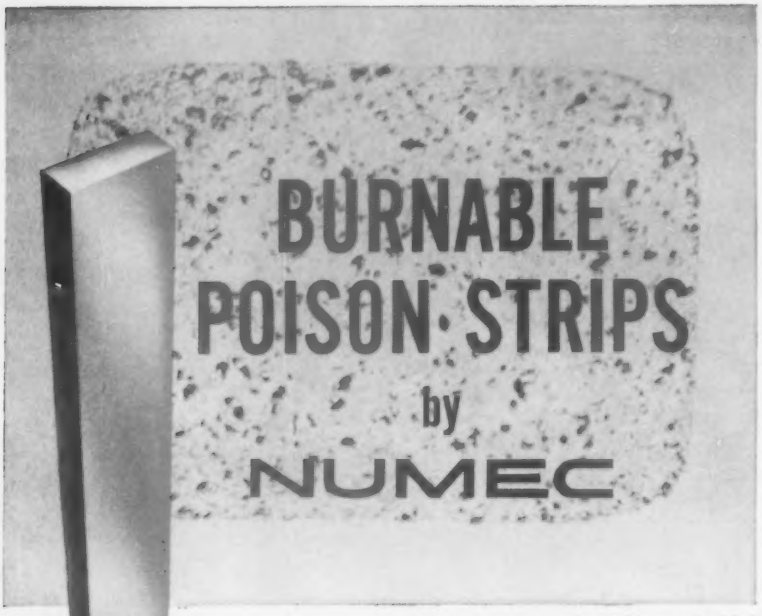
For further information please apply to one of the following addresses:

N.V. PHILIPS' GLOEILAMPENFABRIEKEN, Scientific Equipment Department, Eindhoven-Holland
RESEARCH & CONTROL INSTRUMENTS LTD., Instrument House, 207/215, King's Cross Road, London WC1
PHILIPS ELECTRONICS INC., Instruments Division, 750, South Fulton Avenue, Mount Vernon N.Y. U.S.A.



Actual Photograph of B_4C

. . . help build the Nuclear Navy

Our experience with the problems of the Nuclear Navy began before NUMEC was founded, for many of our personnel played key parts in the development of the *Nautilus*, *Sea Wolf*, *D1G* and *A1W*.

NUMEC itself continues to provide vital services and materials, for example:

Burnable Poison Strips: Boron carbide dispersions in high-purity Zircaloy 2 powder, co-extruded in Zircaloy 2 sleeve. Composite dispersions must meet very stringent corrosion specifications of reactor grade Zircaloy 2. Distribution of the boron carbide must be highly uniform. NUMEC is the foremost producer of these strips.

Reactive Metal Powders: Niobium, zirconium, tantalum and vanadium melted, attritioned and fabricated to specified compositions under special controlled atmospheres.

Special Services: Corrosion testing, both short-time and life: chemical and isotopic analyses of reactor core materials; high-temperature tensile testing of Zircaloy tubing; metallographic and grain size analyses of special materials.

NUMEC's services, facilities and personnel are described in our brochure "Presenting NUMEC." May we send you a copy?

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PRODUCTS & MATERIALS

Department starts on page 144

allowing a particular peak to be centered in a particular 20-channel group.—The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Infrared Spectrometer

Model IR-7 prism-grating infrared spectrometer is capable of grating operation throughout the 2.5–16.6-μ range. The most complete infrared spectrum of ammonia ever produced was run on the IR-7, thus demonstrating the operation of the instrument throughout the entire wavelength range.—Beckman Scientific & Process Instruments Div., 2500 Fullerton Rd., Fullerton, Cal.

LITERATURE AVAILABLE

"Electrometer Triode." 8 pp.; The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

"Film-Badge Services." 8 pp.; R. S. Landauer, Jr. & Co., 3920 216th St., Matteson, Ill.

"Cast Titanium and Zirconium." Folder of assorted brochures, Oregon Metallurgical Corp., Albany, Ore.

Simulators. "Nuclear Reactor & Power Plant Simulators," 18 pp.; Minneapolis-Honeywell Regulator Co., Systems Engineering Div., Wayne & Windrim Aves., Phila. 44, Pa.

"Mounted NaI(Tl) Crystals." 1 p.; The Harshaw Chemical Co., Cleveland 6, Ohio.

"Boron, Borides & Boron Alloys." 4 pp.; Cooper Metallurgical Assoc., Box 3991, Cleveland 20, Ohio.

"Zirconium." 4 pp.; Harvey Aluminum, Torrance, Cal.

Neutron counters. Two 1-p. bulletins; Reuter-Stokes Electronic Components Inc., 2149 Hamilton Ave., Cleveland 14, Ohio.

"Radiochromatographs." 4 pp.; The Forro Scientific Co., 833 Lincoln St., Evanston, Ill.

"Electron-Beam Processing." 34 pp.; High Voltage Engineering Corp., Burlington, Mass.

Mass spectrometry. "Mass Spectrometer," 16 pp. and "Analytical Laboratory Service," 4 pp.; Consolidated Electrodynamics Corp.,

Analytical & Control Instrument Div., 300 N. Sierra Madre Villa Pasadena, Cal.

Beryllium oxide. "UOX-BeO," 12 pp.; The Brush Beryllium Co. Cleveland, Ohio.

Compression-formed seamless tubing. Bulletin SP-1, 4 pp.; Tube Reducing Corp., P.O. Box 959, Passaic, N. J.

"Compact High-Voltage Power Supplies." 4 pp.; Del Electronics Corp., 521 Homestead Ave., Mount Vernon, N. Y.

Nuclear power. "How to Implement Nuclear Power Acceleration," 24 pp.; General Electric Co., Atomic Power Equipment Dept., 2151 S. First St., San Jose, Cal.

Nuclear capabilities. "Ready-to-go-Facilities, Experience, People for Your Nuclear Program," 4 pp.; Tapco Group, Thompson Ramo Wooldridge Inc., Cleveland 17, Ohio.

Filters. "Filtration Catalog," 48 pp.; Flanders Filters Inc., Riverhead, N. Y.

Closed-circuit industrial T.V. 8 pp.; Kintel, Div. of Cohu Electronics Inc., 5725 Kearny Villa Rd., San Diego 11, Cal.

Electronic control system. Bulletin A1.3-1A, 4 pp.; The Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.

High-voltage bushings. Bulletin A-40, 16 pp., Alite Div., The U. S. Stoneware Co., Akron, Ohio.

"Solenoid Valves for Reactors." 4 pp.; Automatic Switch Co., 50–56 Hanover Rd., Florham Park, N. J.

Power supplies & voltmeters. Catalog C-59, 16 pp.; John Fluke Manufacturing Co. Inc., 1111 W. Nickerson St., Seattle 99, Wash.

"GRB Silicon Carbide." Silicon-carbide-bonded graphite, 4 pp.; Carborundum, New Products Branch, Research & Dev. Div., Niagara Falls, N. Y.

"Aluminum Tube and Shapes." 32 pp.; Wolverine Tube, 17200 Southfield Rd., Allen Park, Mich.

Radioisotope-energized markers. Bulletin 30.32, 2 pp.; U. S. Radium Corp., Morristown, N. J.

"Arc-Cast Molybdenum & Mo-0.5% Ti Alloy." 24 pp.; Refrectomet

Radiation Shielding windows give the Navy a direct look into nuclear reactors

In the Navy's new nuclear subs you'll find giant "peepholes"— windows that permit a *direct* look into the reactor compartments. Twelve of these atomic peepholes, weighing half a ton or more, have been ordered from C.G.W. by Westinghouse Electric Corporation for installation in the Navy's new sub fleet. Westinghouse designed and developed the nuclear reactors for the submarines under the direction of and in technical cooperation with the Naval Reactors Branch, U. S. Atomic Energy Commission.

These are weighty windows, made of Corning's high-lead-content glass and a plastic material. The latter shields against neutron bombardment; the high-density *glass* shields against gamma rays.

Round and encased in a metal housing, these radiation shielding windows are part of a complete line made by and available from Corning.

For details on types of glass, transmittance and shielding characteristics, darkening, and design considerations, ask for Bulletin PE-51, "Corning Radiation Shielding Windows."

Direct your inquiries to Corning Glass Works, 16 Crystal Street, Corning, N. Y.

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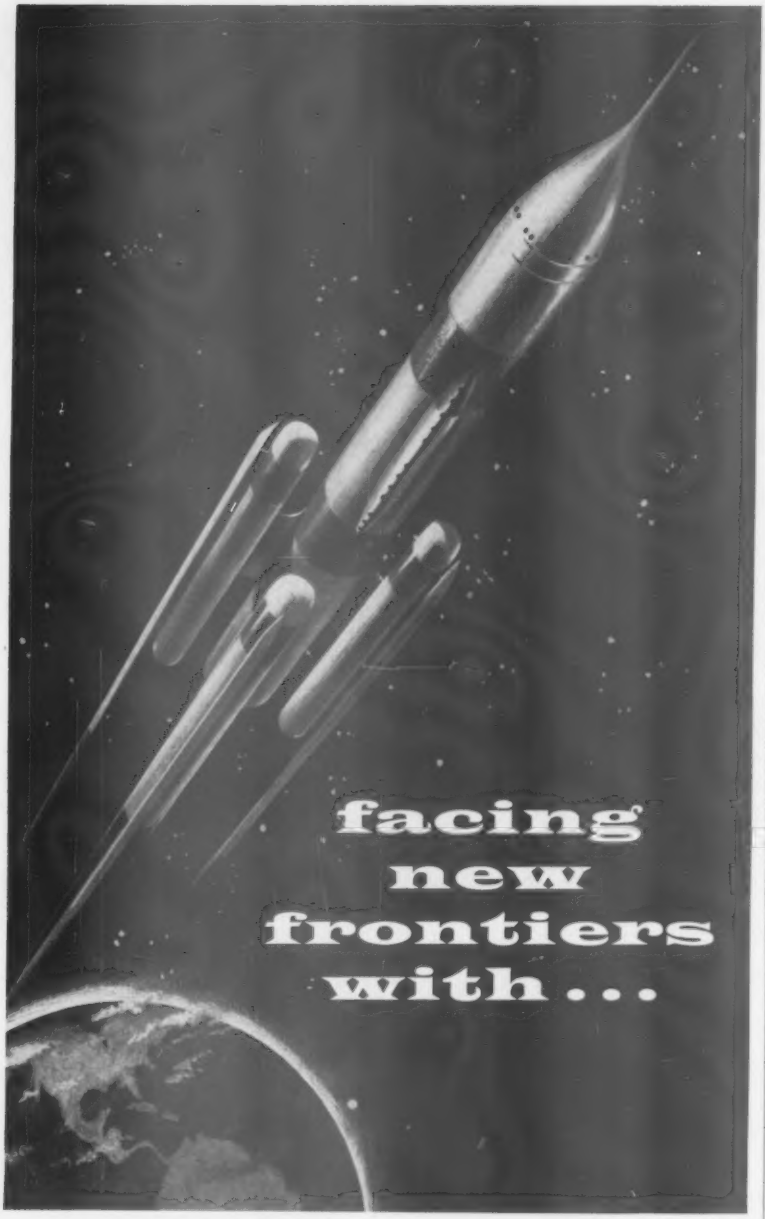

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PRODUCTS & MATERIALS

Department starts on page 144

Div., Universal-Cyclops Steel Corp., Bridgeville, Pa.

Nuclear power in southern Italy. Summary Report of the International Panel on Project ENSI, 30 pp.; World Bank, 1818 H St., N. W. Wash. 25, D. C.

Reactor metals. Bulletin IND-20, 8 pp.; Metals & Controls Corp.; General Plate Div., Attleboro, Mass.

Canned pumps. Technical Bulletin 4, 7 pp., Chempump Corp., 1300 E. Mermaid Lane, Phila. 18, Pa.

Monitoring of foodstuff. Special Report, 9 pp.; Radiation Counter Laboratories, Inc., 5121 W. Grove St., Skokie, Ill.

Tubular components. "TI's Contribution to the Nuclear Engineering Industry," 26 pp.; Tube Investments, Nuclear Engineering Ltd., The Adelphi, London WC2, England.

"High Vacuum Equipment." 8 pp.; Veeco Vacuum Corp., 86 Denton Ave., New Hyde Park, N. Y.

Recording spectrophotometer. Bulletin 114, 12 pp.; Applied Physics Corp., 2724 S. Peck Rd., Monrovia, Cal.

"Constant-Air-Flow Hood." Catalog DH3, Duralab Equipment Corp., 989 Linwood St., Brooklyn 8, N. Y.

Spectroscopes. Bulletin 154–58, 4 pp.; Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

Scintillation well counter. Bulletin SC-1, 2 pp.; Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

Radiation detection equipment. "Tubes by E.M.I. Electronics Ltd," 2 pp.; and "Nuclear Radiation Detection System," 2 pp.; H. L. Hoffman & Co., Inc., 35 Old Country Rd., Westbury, N. Y.

Reactor trip-amplifier/alarm. Bulletin E12-10, 4 pp.; Bailey Meters & Controls Ltd., Purley Way, Croydon, Surrey, England.

"Miniature Electronic Control Meter." 4 pp.; International Instruments Inc., New Haven, Conn.

Expansion joints. "Quick Guide to Expansion Joint Selection," 4 pp.; Zallea Brothers, 815 Locust St., Wilmington 99, Del.

Products and Services Directory—Supplement

Not unexpectedly, considering the tight schedule under which it was put together, a number of companies were overlooked in the Products and Services Directory published in the May '59 NUCLEONICS. With apologies to those companies and to our readers, we offer the following supplementary information.

COLUMNS—Absorption
Avery & Saul Co., 115 Rindge Ave. Extension, Cambridge 40, Mass.

COLUMNS—Distilling
Avery & Saul Co.

CONTAINERS—Fuel Element and Shielded
Avery & Saul Co.

CONTROL MATERIALS—Alloys

Company Name	Alloys & Shapes	Purity	Fabrication Processes
Clevite Corp., Mechanical Research Div., 540 E. 10th St., Cleveland 8, Ohio	B-ss		welding, roll-cladding
Cooper Metallurgical Associates, Box 3991, Cleveland 20, Ohio	Al-B bars	99+%	
	Cu-B bars	99+%	
New Process Metals, Inc., 45-65 Manufacturers Place, Newark 5, N. J.	Misch metal		

CONTROL MATERIALS—Boron

Company Name	Shapes	Purity
Cooper Metallurgical Assoc.	powder	99.6%
	arc-melted (large granules)	high

CONTROL MATERIALS—Cerium

Company Name	Shapes	Purity
New Process Metals, Inc.	ingot, rod, pellet, turnings	98+% or 99.5+%

CONTROL MATERIALS—Lanthanum

Company Name	Shapes	Purity
New Process Metals, Inc.	ingot	99.5+%

COUNTERS—Alpha, Beta
Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.

COUNTERS—Gamma

Company Name	Operating Range	Counting Rate	Accuracy	Portable
Hamner Electronics Co., Inc., Box 531, Princeton, N. J.	10 kev–8 Mev	50,000 cps	±1%	yes
Nuclear Measurements Corp.				

COUNTERS—Geiger-Muller
Nuclear Measurements Corp.

COUNTERS—Neutron

Company Name	Operating Range	Counting Rate	Accuracy	Portable
Hamner Electronics Co., Inc.	slow–fast	50,000 cps	±1%	no

COUNTERS—Proportional
Nuclear Measurements Corp.

COUNTERS—Scintillation

Company Name	Operating Range	Counting Rate	Accuracy	Portable
Hamner Electronics Co., Inc.	10 kev–8 Mev	70,000 cps	±1%	no
Nuclear Measurements Corp.				

DECONTAMINANTS—Chemical
Charles Pfizer & Co., Inc., Chemical Sales Div., 630 Flushing Ave., Brooklyn 6, N. Y.

EVAPORATORS
Pacific Coast Engineering Co., Oak St. & Clement Ave., Alameda, Calif.

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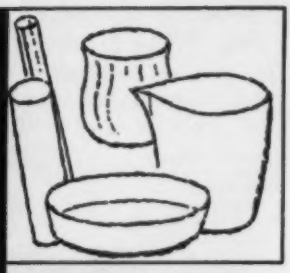

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P. O. Box 733 Silver Spring, Maryland

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for tracer counting

Special Plastic Capillary Flow Counter for quick and reproducible counting of Betas in aqueous solution in flow or static systems (Bulletin 16).
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Thin sheets of Plastic Phosphor NE102 for beta counting.
Other products include: Thermal and fast neutron solid Scintillation detectors, loaded Liquid Scintillators and Scintillation chemicals.

NUCLEAR ENTERPRISES LTD.
1750 Pembina Highway
WINNIPEG 9, CANADA
Associate Co.: Nuclear Enterprises (G.B.) Ltd.
Sighthill, Edinburgh 11, Scotland

Products and Services Directory—Supplement

(Continued)

FUEL ELEMENTS

Company Name	Maximum Enrichment	Materials Handled	Burnup Warranty	Fabricated Shapes
Clevite Corp., Mechanical Research Div.	fully	Zr, Al, ss, UO_2, U metal	yes	plate, pellet, tube

HEAT EXCHANGERS—Liquid to Air, Liquid and Steam

Avery & Saul Co.
Pacific Coast Engineering Co.

MANIPULATORS

Pacific Coast Engineering Co.

MONITORS—Air Particles

Nuclear Measurements Corp.

MONITORS—Area Radioactivity

Company Name	Operating Range	Counting Rate	Accuracy	Portable
Hamner Electronics Co., Inc.	up to 8 Mev	50,000 cps	±1%	no
Nuclear Measurements Corp.				

MONITORS—Gas, Water

Nuclear Measurements Corp.

PRESSURE VESSELS

Avery & Saul Co.
Pacific Coast Engineering Co.

PRESSURIZERS

Avery & Saul Co.

REACTOR INSTRUMENT SYSTEMS—Nuclear

Borg-Warner Corp., 3300 Newport Boulevard, Santa Ana, Calif.
Hamner Electronics Co., Inc.

REFUELING EQUIPMENT—Reactor

Pacific Coast Engineering Co.

SCINTILLATORS—Crystal

Company Name	Operating Range	Accuracy	Shapes
Hamner Electronics Co., Inc.	beta and gamma	2%	up to 3″ × 5″

SCINTILLATORS—Plastic

Nuclear Measurements Corp.

SERVICES, DECONTAMINATION

Charles Pfizer & Co., Inc., Chemical Sales Div.
Interstate Industrial Uniform Rental Service, Decontamination Laundry Div., 295 Parker St. Springfield, Mass.

VALVES

Blaw-Knox Co., Copes-Vulcan Div., 939 West 26th St., Erie, Pa.
Foreign representative: Copes Regulators Ltd., 9, Southampton Place, London, W.C.1. England

	Bellow Seal	Pressure Regulating	Pressure Reducing
Size range	1″–24″	1″–24″	1″–24″
Rating range	150–2,500	150–2,500	150–2,500
Oper. Temp. range	1,100° F	1,100° F	1,100° F
Oper. press. range	to 3,000 psig	to 3,000 psig	to 3,000 psig
Fluids handled	Na, H_2O	H_2O, steam	H_2O, steam

INDUSTRY NOTES

• Directors of **Victoreen Instrument** and **Tenney Engineering** have decided to merge their firms, creating **Victoreen-Tenney Corp.** with annual sales of about $15-million. Merger is subject to stockholder approval at meetings in late September for each company.

• **Union Carbide Nuclear** has completed three of the five buildings of its Sterling Forest, N. Y., research center —the main lab, a power and utilities building and an ore and minerals development lab. A reactor building and associated lab are due for completion in late 1960.

• **High Voltage Engineering** has sold a 6-Mev microwave linear accelerator to the Elizabeth Steel Magee Hospital, Pittsburgh. The machine will be used for cancer therapy and research.

• **New England Nuclear** has announced across-the-board price reductions, effective July 1, for all cataloged carbon-14 labeled compounds. The decreases of 5–20% reflected an earlier reduction in the price of barium-carbonate-C^{14} by AEC.

• **Sargent & Lundy** has given full departmental status to its nuclear operations—"placing more emphasis on this phase of our work." Fred W. McCloska will head the department.

• **Gerard G. Leeds Co.** has given up its corporate identity in favor of four new firms formed by its branch managers. President Gerard G. Leeds will devote full time to **Lumatron Electronics, Inc.,** manufacturer of millimicrosecond instrumentation.

NEW FIRMS. The first company to offer regularly scheduled training programs in the nuclear field—**Radiation Engineered Services**—has been headquartered at Lafayette and Water Sts., Norristown, Pa. Courses began in August on the first two of 12 subjects being offered (*see page 162*). . . . **Atomium Corp.,** Waltham, Mass., has been created to provide nuclear medical instrumentation with emphasis on complete systems; President Hugh F. Stoddard was formerly with Baird-Atomic. . . . **Atom Apply,** Box 73, St. Ann, Mo., is offering design, fabrication, transportation and applications advice on "all things nuclear." . . . **Gilliland Instruments Co.,** Oakland, and **Nuclear Research Instruments,** San Francisco, have formed a joint venture to produce Franckenstein measuring projectors—**Gilliland-NRI.** The instrument quickly and automatically measures the paths of atomic particles in bubble chambers. . . . **Nuclear Data, Inc.,** has been formed at Wheaton, Ill., for development and manufacture of advanced electronic instrumentation—with initial emphasis on radiation analyzing equipment. . . . **Vitro Idaho Minerals Corp.** has been set up jointly by **Vitro Minerals Corp.** (51%) and **Western Fluorite Mining** (49%) at Salt Lake City; the new firm will develop and mine properties in Idaho and the Pacific Northwest. . . . **U. S. Nuclear,** P. O. Box 2002, Burbank, Calif., has entered the isotope field, offering radioactive sources, labeled compounds, shielding and handling equipment, services (consulting, decontamination, health physics, analyses and waste disposal) and training courses.

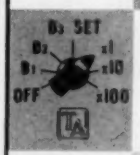
EXPANSIONS. A 70,000 sq ft facility in Franklin Park, Ill. has been occupied by **Nucledyne div.** of Cook Electric Co. . . . **Technical Operations** has begun construction of two new buildings—one at Burlington, Mass., for research into nuclear weapons effects and industrial radiography and the other in Stamford, Conn., for its film-processing subsidiary, Chemtrol Corp. . . . **Nuclear-Chicago Corp.** has established an Industrial div. for the marketing, applications engineering and design engineering of radioisotopes for production processing.

NEW BUSINESS. Under a $77,100 contract from AEC, **Nuclear Materials and Equipment Corp.** has entered the scrap recovery business (29,000 gm U from uranium-zirconium alloy chips and various solutions, plus 23,500 gm U contained in rejected fuel plates and unclad compacts); a $6,047 contact for recovery of 7,500 gm U from uranium-aluminum alloy went to **Englehard Industries.** . . . **Edlow Lead Co.** has won contracts for supply of shipping casks for irradiated fuel elements from AMF Atomics, Allis-Chalmers, Socony Mobil, Naval Research Laboratory, and two foreign customers. Edlow has recently signed a patent and technical assistance **licensing agreement** with Paul Bergsoe and Sons, Glostrup, Denmark.

T/A Model CP-3 offers important new features!

- **Alpha-sensitive.**
- **Built-in alpha and beta absorption filters.**
- **New battery pack provides over 800 hrs. operating life.**
- **Entire battery complement can be checked before use.**

Alpha and/or beta radiations are easily rejected by swinging the proper absorber into place.



RANGE SELECTOR SWITCH includes 3 test positions for checking all batteries prior to use.

CP-3 is equipped with tripod feet for table or floor monitoring.

T/A Model CP-3 Cutie Pie measures and distinguishes between alpha, beta, and gamma radiation, and is designed for laboratory, reactor, and industrial use. This portable instrument features three full-scale ranges of 50, 500, and 5000 mr/hr, and is especially useful in health physics work.

Write for Bulletin No. 165

TECHNICAL ASSOCIATES
Instrumentation for Nuclear Research
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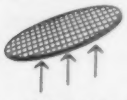
a filter man's thinking

"Expediency: when time is more precious than gold (or platinum)"

BY JULES P. KOVACS, V. P., PUROLATOR PRODUCTS, INC.

There's more than one way to skin a cat . . . or filter a chemical that fights any attempt to tame it.

As an example, here's a problem we recently licked in developing a diffusion plate bed support for a highly corrosive gaseous fluidized bed reactor, operating at very high temperatures. Pore size had to be 25 microns, able to support 20 psi. And it was needed in a *hurry*.



Now, anyone who knows filters could pick metals for such a job. The obviously ideal medium would be inconel. Trouble was, it was impossible to obtain a fine enough inconel screen. Of the only other metals that could withstand the corrosive action, gold lacked high temperature strength; platinum was too weak without support and too costly, though it did offer the high temperature strength and corrosion resistance needed. And that's where Purolator's special capabilities came into play.

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NEWSMAKERS

Yankee Atomic Electric Co. has selected the seven men who will run its 110-Mw(e) pressurized-water power reactor when it goes into operation next year. **Glen A. Reed,** plant superintendent; **Carroll E. Haseltine, Jr.,** chief engineer; **Walter J. Miller,** technical manager; **J. Edward Howard,** reactor engineer; **David A. Hansen, Jr.,** control engineer; **Louis H. Heider,** chemical engineer; and **Alfred E. Davies,** maintenance supervisor.

Morton Hamermesh has been named director of the Physics div. at Argonne National Laboratory. He succeeds **Louis A. Turner,** who had earlier been appointed deputy to Argonne Director Norman Hilberry. Hamermesh has been in the AEC program for 11 years, all of it with Argonne; he had been associate director of the Physics div. since 1951.

Hamermesh

The first and only editor of the journal of the American Nuclear Society—**James G. Beckerley** of Schlumberger Well Surveying Corp.—has resigned. Beckerley will continue to edit Nuclear Science and Engineering until a successor is named.

Frank Zeitlin has been named vice-president of Mallinckrodt Nuclear Corp., wholly-owned subsidiary of Mallinckrodt Chemical Works.

New manager for research and development operations at Nuclear Development Corp. of America is **J. Ernest Wilkins, Jr.,** a mathematician and NDA employee since 1950. He succeeds **Sidney Liebson,** who has joined Armour Research Foundation. Wilkins is a charter member of the American Nuclear Society; his nuclear background dates back to the Manhattan project. **Matthew Shapiro** has been named his deputy.

Wilkins

Sylvania-Corning Nuclear Corp. has added eight people to its Commercial Production unit and given one of its veteran employees a new post. New staffers are: **John M. Zabkar** (formerly of Westinghouse), chief of manufacturing operations; **Richard A. Alto** (Westinghouse), supervisor of production control; **Harold R. Diot** (duPont, Foster Wheeler), chief of aluminum-fuel projects; **John R. Dickson** (General Electric), chief, commercial planning and control dept.; **William C. Herman** (Olin Mathieson), quality control engineer; **H. Robert Clayton, Jr.** (Alco), chief, quality control dept.; **Charles S. Fee** (Westinghouse), project manager, ceramic fuels contracts; **B. H. Francis** (Westinghouse), project manager for production of fuel for the Fermi reactor. **William G. Lidman** has been promoted to project manager of all Sylcor activities on the Army Package Power Reactor, Ft. Belvoir, Va.

Key posts on General Atomic's two high-temperature gas-reactor projects have been filled by **W. C. Moore,** project manager for the Maritime Gas-cooled Reactor, and **Hugh B. Stewart,** who will direct the physics program of the High Temperature Gas-cooled Reactor. Moore, who has spent 14 years with Union Carbide, has had long experience in AEC's gaseous diffusion program, including substantial design and development work on the diffusion plants at Paducah, Ky., and Portsmouth, Ohio. Stewart joined GA from Knolls Atomic Power Laboratory (GE), where he was manager of physics for the Naval Destroyer Reactor Program. Moore succeeds **Thomas Pigford,** who will continue as a consultant to GA from his university post at the University of California at Berkeley (professor of nuclear engineering).

Moore

Stewart

Edward L. Brady of KAPL has been named senior scientific and technical advisor to **Paul L. Foster,** U. S. representative to the International Atomic Energy Agency.

The National Aeronautics and Space

Administration has asked **M. A. Schultz,** Westinghouse, to serve on its Research Advisory Committee on Nuclear Energy Processes (flight-vehicle propulsion and power generation). Other committee members are: **Walter H. Jordan** of Oak Ridge National Laboratory, chairman; **Arthur T. Biehl,** Aerojet-General Nucleonics; **Edward A. Frieman,** Princeton Univ.; **Miles T. Leverett,** General Electric; **P. H. Miller, Jr.,** General Dynamics; **Richard F. Post,** Livermore; **R. E. Schreiber,** Los Alamos; **Michael F. Valerino,** General Nuclear Engineering; **Joseph Wetch,** North American Aviation; **Russell D. Shelton,** Redstone Arsenal; **R. L. Dunkin,** USN; **John H. Anderson,** AF; and **Jack Armstrong,** AEC-AF, directing the nuclear rocket program.

Effective March 1, 1960, **Eldon L. Alexanderson** will report to the Fermi reactor of Power Reactor Development Co. as reactor engineer. Alexanderson has been head of the reactor and systems analysis section, Atomic Power Development Associates.

Atomics International has selected **Farris U. Bower,** an engineer with both organic and sodium experience, to direct construction of the 11.4-Mw(e) Piqua reactor (NU, July '59, 28). Bower participated in the construction of the Sodium Reactor Experiment, Santa Susana, Calif., and the Organic Moderated Reactor Experiment, National Reactor Testing Station.

Bower

Isotope Specialties div. of Nuclear Corp. of America has named **Alfred J. Moses,** formerly of Westinghouse Bettis, to manage its radioactive laboratory operations. Other new staffers are: **John D. Vaden,** health physics officer, and **Nyle Schafhauser,** manager, experimental shop.

Paul R. Ellis has been appointed manager, South Albuquerque Works, ACF Industries. The works are operated by ACF for AEC.

GE has named **Hamilton H. Dow** to a resident post with the nuclear destroyer project at Bethlehem Steel Co.'s Quincy, Mass., shipyard. As chief of the Knolls Atomic Power Laboratory field office at Quincy, Dow will supervise receipt and installation of nuclear components.

Two top posts have been filled by Aerojet-General Nucleonics: **Carl R. Malmstrom,** manager of research and development for Rheem Manufacturing Co., has been named assistant general manager; **Hubert P. Yockey,** former assistant director of the Health Physics div. of Oak Ridge National Laboratory, has been named assistant technical director. Malmstrom did some of the early work on nuclear rockets and holds several patents on high-temperature materials; he also designed and conducted some of the first critical experiments at the Lawrence Radiation Laboratory. Yockey's varied nuclear experience includes work on isotope separation, shielding and waste disposal.

Malmstrom

Yockey

John G. Habermeyer has been elected vice-president and director of Radiation Detection Co., Palo Alto, Calif.

Technical management posts have been filled by three nucleonics firms: **Bernard Kopelman,** formerly of Sylvania-Corning, has joined Beryllium Corp. as technical director; **Herbert M. Hershenson,** formerly of Olin Mathieson, has joined Baird-Atomic as assistant technical director for product planning; and **William C. Knopf,** formerly of International Minerals and Chemical, has joined U. S. Industries as technical director of the USI Technical Center, Pompano Beach, Fla.

Myron C. Beekman, director of nuclear power development at Detroit Edison, has been elected chairman of the Detroit Nuclear Council. He succeeds **Douglas W. Anderson,** Parke Davis & Co.

Armour Research Foundation's nuclear physics research supervisor, **Clint A. Stone,** has left the country for a 6–8-week stint in Burma, where he will help to establish a nuclear research laboratory.

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This limited leakage pump for an Atomic Laboratory is shown above undergoing final high temperature seal tests. Parts in contact with pumpage are all of 304 stainless steel.

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NUCLEAR CALENDAR

Sept. 7–11—Ion Exchange Conference, sponsored by American Association for the Advancement of Science, Gatlinburg, Tenn. Contact AAAS, 1515 Mass. Ave., N.W., Washington 5, D. C.

Sept. 13–18—13th National Meeting of American Chemical Society, Atlantic City. Contact ACS, 1155—16th St., N.W., Washington 6, D. C.

Sept. 22–24—3rd Industrial Nuclear Technology Conference on nonpower applications of nuclear technology, cosponsored by Armour Research Foundation and NUCLEONICS, Chicago (*Morrison*). Contact Leonard Reiffel, ARF, 10 W. 35th St., Chicago 16.

Sept. 22–25—Meeting of American Roentgen Ray Society, Cincinnati (*Conrad Hilton*). Contact Dr. C. Allen Good, Mayo Clinic, Rochester, Minn.

Sept. 28–Oct. 1—Ninth Annual Instrument Symposium and Research Equipment Exhibit, Bethesda, Md. (*National Institutes of Health*). Contact James B. Davis, NIH, Public Health Service, Bethesda 14.

Sept. 28–Oct. 1—National Power Conference, cosponsored by American Society of Mechanical Engineers and American Institute of Electrical Engineers, Kansas City (*Muehlebach*). Contact ASME or AIEE, 33 W. 39th St., N. Y., N. Y.

Oct. 6–9—International Symposium on High-Temperature Technology, Asilomar, Calif., sponsored by Stanford Research Institute. Contact Dept. 734, SRI, Menlo Park, Calif.

Oct. 7–9—National Symposium on Vacuum Technology, sponsored by American Vacuum Society, Philadelphia (*Sheraton*). Several nuclear sessions. Contact C. B. Willingham, AVS, Box 1282, Boston, Mass.

Oct. 14–16—12th Annual Gaseous Electronics Conference, sponsored by Electron Physics div. of American Physical Society and National Bureau of Standards, Washington, D. C. (*Sheraton-Park*). Contact L. M. Branscomb, NBS, Washington, D. C.

Oct. 15–16—Radiation Effects Symposium of Glass Div., American Ceramic Society, Galen Hall, Pa. Contact Norbert Kreidl, Bausch and Lomb Optical Co., Rochester 2, N. Y.

Oct. 26–28—Third Conference on Analytical Chemistry in Nuclear Reactor Technology, Gatlinburg, Tenn. Contact C. D. Susano, Oak Ridge National Laboratory, P. O. Box Y, Oak

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Oct. 26–28—3rd Conference on Analytical Chemistry in Nuclear Reactor Technology, Gatlinburg, Tenn. Contact C. D. Susano, Oak Ridge National Laboratory, P.O. Box Y, Oak Ridge, Tenn.

Nov. 2–6—Joint Meeting of Atomic Industrial Forum and American Nuclear Society, Washington, D. C. (*Sheraton Park*). AIF's annual meeting scheduled first three days (Nov. 2–4), ANS' semiannual meeting begins third day (Nov. 4–6). For AIF meeting contact AIF, 3 E. 54th St., N. Y. 16, N. Y.; for ANS meeting contact ANS, 86 E. Randolph St., Chicago 1.

Nov. 4–6—National Automatic Control Conference, Dallas (*Sheraton*), sponsored by Institute of Radio Engineers. Also participating: American Institute of Electrical Engineers and Instrument Society of America. Contact G. S. Axelby, Westinghouse, Box 746, Baltimore 3, Md.

Nov. 4–6—Eastern Analytical Symposium and Instrument Exhibit, New York City (*New Yorker*), sponsored by four Eastern sections of Society for Applied Spectroscopy, among others.

Nov. 15–20—Conference of Radiological Society of North America, Chicago (*Palmer House*). Contact RSNA, 815 Medical Arts Bldg., Ft. Worth, Tex.

Nov. 16–21—Conference on Disposal of Radioactive Wastes, Monaco, sponsored by International Atomic Energy Agency. Contact IAEA, 11-13 Karntnerring, Vienna 1.

Nov. 19–20—Sixth Annual Meeting of the Professional Group on Nuclear Science of the IRE in conjunction with the New England Regional Electronics Meeting, Boston, Mass. (*Commonwealth Armory*). Contact Hugh Stoddart, Atomium Corp., 940 Main St., Waltham, Mass.

Dec. 7–9—Seminar on Nuclear Ship Propulsion (with special emphasis on safety) sponsored by the International Atomic Energy Agency, Vienna. Contact IAEA 11–13 Karntner Ring, Vienna 1, Austria.

Feb. 25–26—7th Scintillation Counter Symposium, Washington, D. C. (*Shoreham*). Deadline for abstracts is Dec. 15. Contact G. T. Reynolds, Princeton Univ., Princeton, N. J.

April 3–8—6th Nuclear Congress, New York City (*Coliseum*). Includes 6th Nuclear Engineering & Science Conference, 8th Atomic Energy in Industry Conference and 6th International Atomic Exposition. Contact E. B. Gunyou, Curtiss-Wright Corp., Princeton, N. J.

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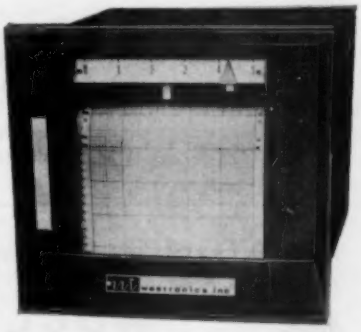

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NUCLEAR CAMPUS

• **CAMPUS FACILITIES.** The $609,000 pool-type reactor ordered by **Washington State College** from General Electric is expected to be completed this year. The reactor will operate initially at 100-kw and will be similar to Oak Ridge's Bulk Shielding Reactor. . . . **Penn State** is expanding its nuclear research program with the aid of grants from AEC and Westinghouse; the latter contributed more than half the cost of a $359,000, 5½-Mv Van de Graaf positive-ion accelerator and AEC has okayed a 3-year grant of $571,400 for special equipment and research support. The school will seek state funds for a building to house the accelerator. . . . **North Carolina State College** has reactivated its "Raleigh Reactor" after a move to a new campus location; it was moved to make room for the 10-kw reactor to be completed by Nucledyne div. of Cook Electric this fall. . . . **Cornell Univ.** has completed plans for a Center for Nuclear Technology; under order for the Center are a tank-type reactor from Curtiss-Wright and a Triga training reactor from General Atomic. Total construction cost of the Center—designed by Vitro Engineering—is estimated at $1,550,000; completion target date is June 1961.

• AEC has launched a "Mobile Isotopes Training Program" featuring a **mobile training lab** to be driven from campus-to-campus in conjunction with a two-week course on basic techniques of radioisotope handling. First campus visits will be to colleges in the South and Southeast. Contact University Relations div., Oak Ridge Institute of Nuclear Studies, P.O. Box 117, Oak Ridge, Tenn.

• AEC has also inaugurated a program of special fellowships for advanced training in **health physics.** Five fellowships annually are available, beginning in the 1959–60 academic year ($4,000, plus $400 per dependent—with up to $2,500 available to the graduate school of choice). Contact ORINS (*see above*).

• **COURSES.** **Radioisotopes in industry** is offered at Oak Ridge Oct. 12–Nov. 20. Contact Ralph T. Overman, Special Training div., ORINS.

Radiation Engineered Services, Norristown, Pa., is offering **basic nucleonics** (Sept. 7–18), **applied nucleonics** (Sept. 21–Oct. 2), **nucleonics for the editor** (Oct. 5–9) and **nucleonics for the executive** (Oct. 12–16).

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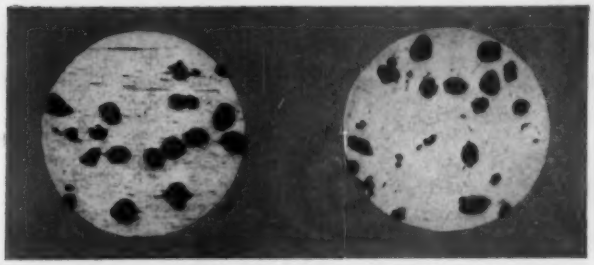
NARROWING THE "DEPARTURE FROM IDEALITY" IN DISPERSION FUEL DEVELOPMENT



† Longitudinal section of 200-μ UO_2 dispersed in Zircaloy matrix. 30X. BF. Reduced approximately 38% for reproduction.

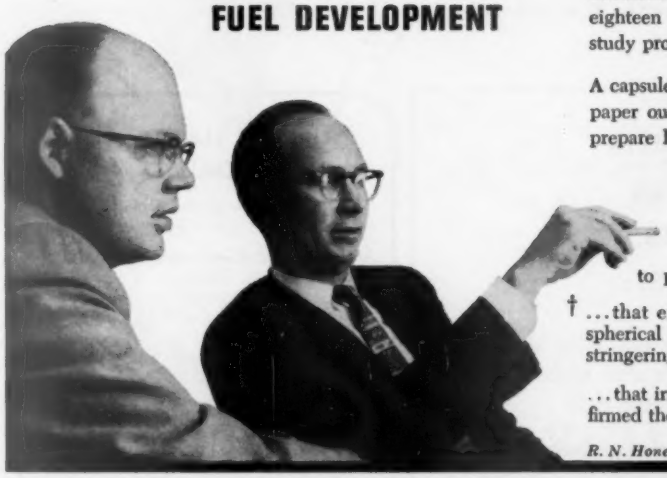
Transverse section of 200-μ UO_2 dispersed in Zircaloy matrix. 30X. BF. Reduced approximately 38% for reproduction.

Scientists have long been cognizant of the theoretical advantages of applying the dispersion theory to reactor fuel elements. Ideally this concept could be utilized to extend substantially fuel rod life in high performance water cooled reactors.

But it remained for KAPL Metallurgists Dr. A. P. Beard and R. N. Honeyman to solve basic problems of process metallurgy involved and achieve *actual fabrication* of zirconium-alloy base dispersion elements which were a significant step closer to the theoretical ideal.

Encouraged by Dr. C. E. Weber, Manager of Basic Materials Development, and a leading figure in Dispersion Element research — and aided by consultation with specialists in several KAPL laboratories — Beard and Honeyman successfully completed evaluation of the irradiation behavior of their first samples in September 1958, only eighteen months (and 2 volumes of experimental data) after the study program was formally initiated.

A capsule description of their findings appears below. Reprints of a paper outlining the experimental method and techniques used to prepare laboratory samples will be furnished on request.



R. N. Honeyman (l.) and A. P. Beard (r.)

Summary of Findings: Dispersion Fuel Study

...showed that mechanical attritioning could be used to prepare zirconium powder with high corrosion resistance.

† ...that extrusion of dispersions of 200 micron dia. particles of spherical UO_2 & UC could be achieved at 750° C with little or no stringering and no reaction between particles and Zircaloy matrices.

...that irradiation behavior of zirconium base dispersion fuels confirmed theoretical concepts of such systems.

Engineers and scientists who appreciate an environment where free inquiry and creative initiative are encouraged are invited to investigate these immediate openings: **Mechanical metallurgy ★ Mathematical statistics & design of experiments (PhD) ★ Mathematical analysis & computer programming ★ Theoretical reactor physics ★ Experimental reactor physics ★ Advanced numerical analysis (PhD) ★ Advanced engineering mathematics (PhD) ★ Materials irradiations experiments ★ Shielding design ★ Reactor materials development ★ Powerplant performance evaluation ★ Analytical chemistry, X-ray diffraction ★ Applied ceramics ★ Radiochemistry ★ Reactor structural design ★ Primary & secondary systems design ★ Chemical analysis, vacuum techniques ★ Reactor instrumentation ★ Nuclear analysis ★ Reactor operation ★ Computer operations ★ Materials quality control ★ Coolant technology ★ Process development metallurgy**

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See Page 1 for description of one phase of B&W's nuclear activities.

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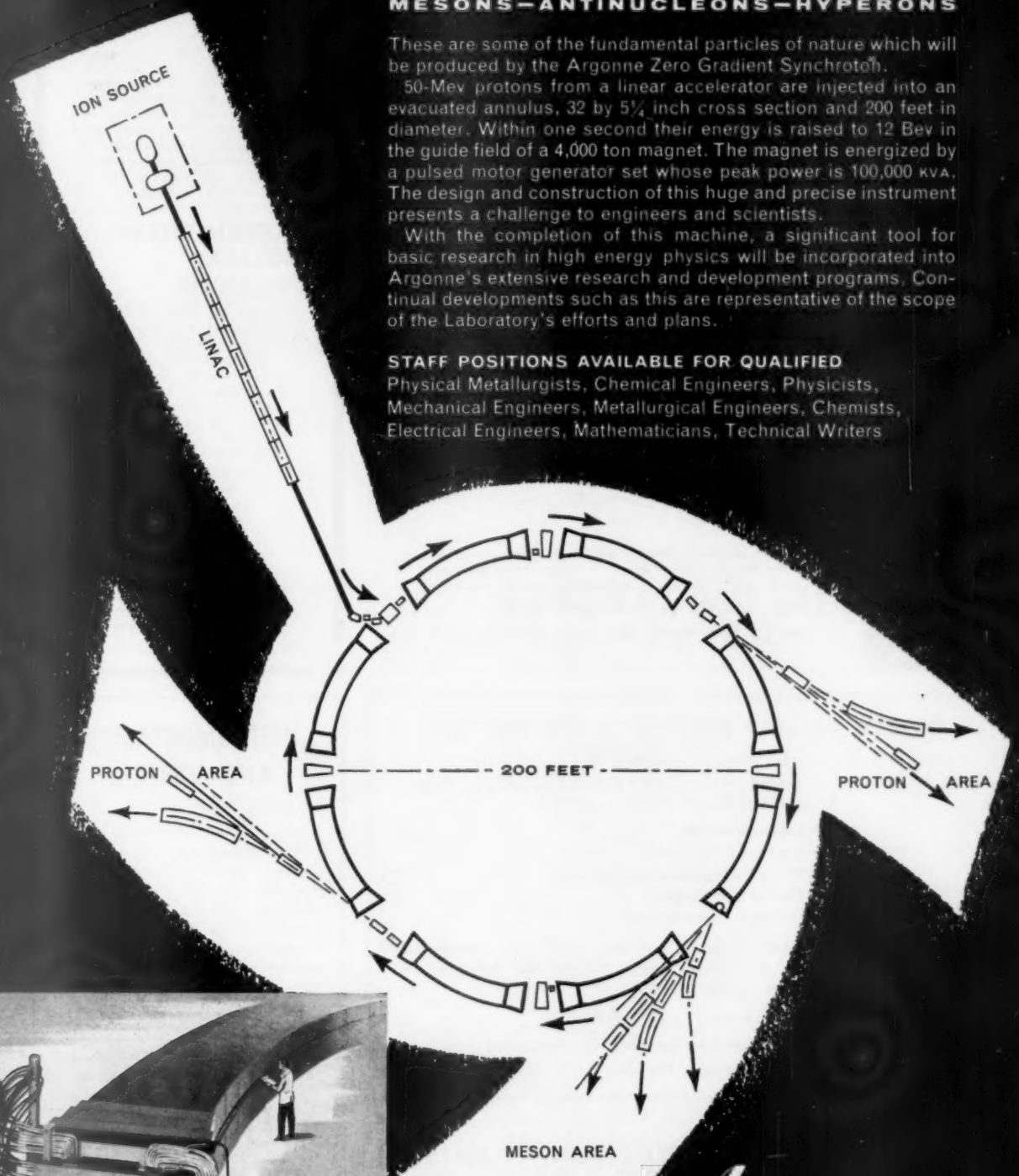

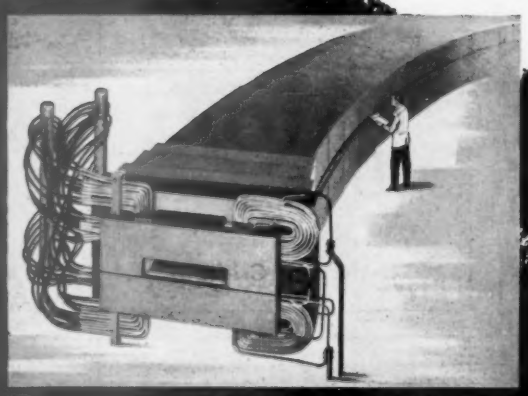

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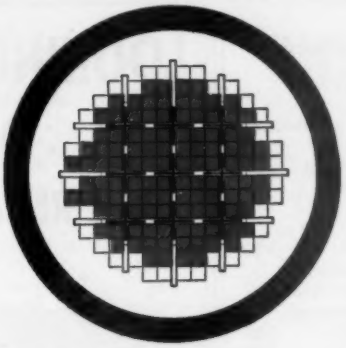

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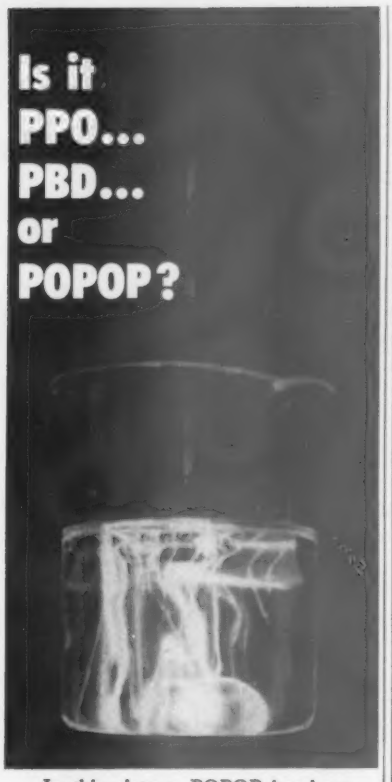

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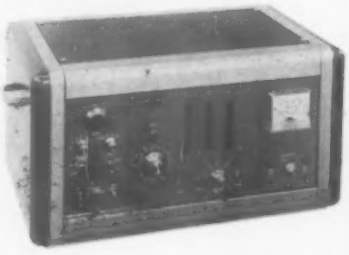

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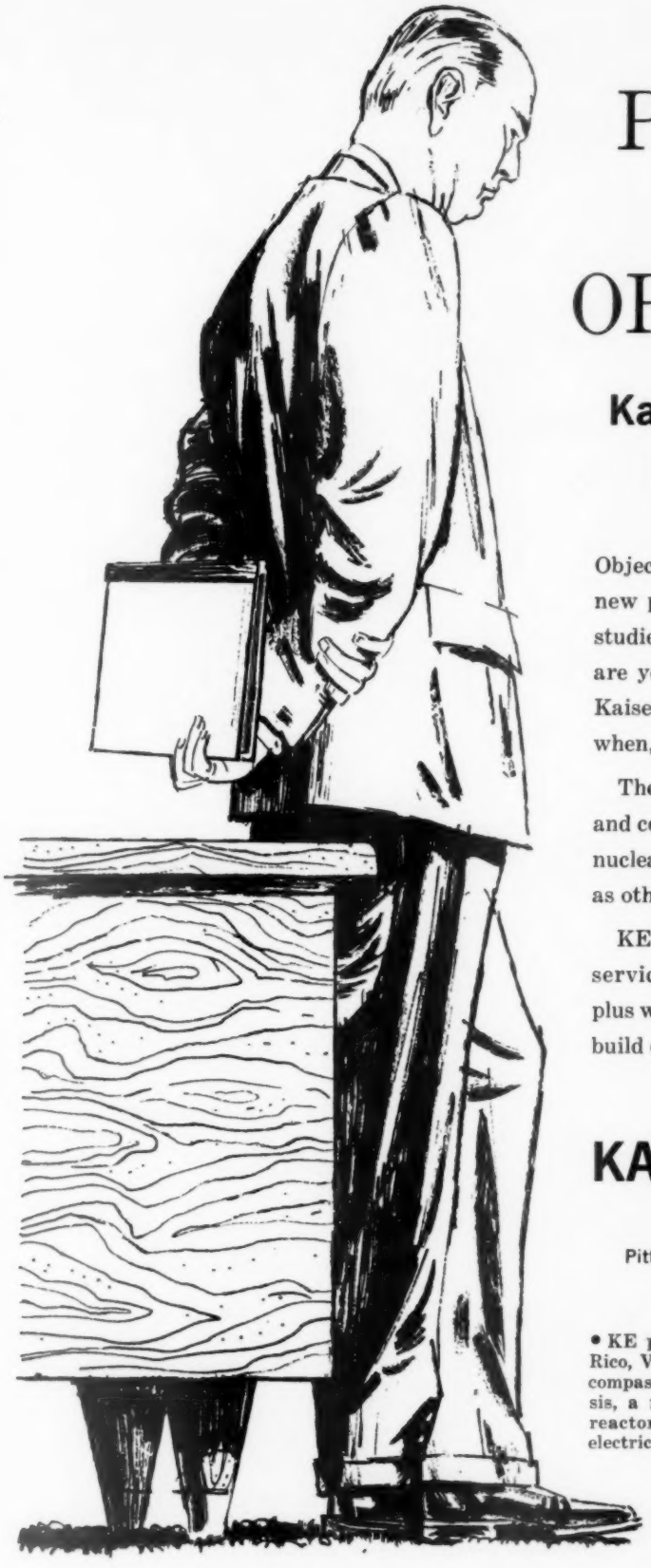

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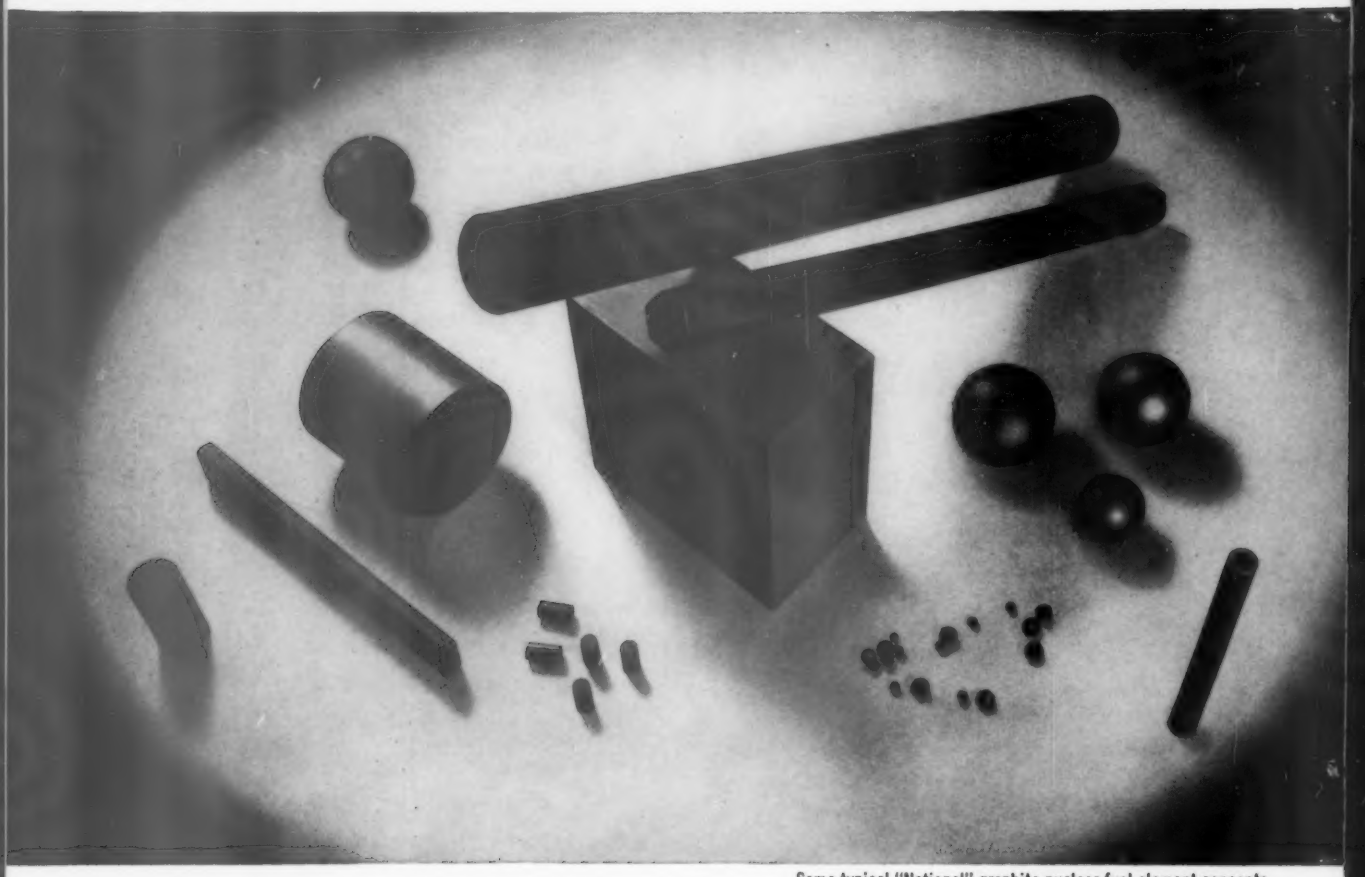

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